BEET-SUGAR MANUFACTURE

AND

REFINING

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Vol. II

EVAPORATION, GRAINING AND FACTORY CONTROL

BY

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BEET-SUGAR MANUFACTURE.

PART IV.

EVAPORATION.

CHAPTER I.

GENERAL CONSIDERATIONS.

Necessity of concentration.—Sugar when in solution will not crystallize unless brought to a given concentration, to which there is a limit that cannot be exceeded. For all crystallizable substances there is a limit of solubility which varies with the temperature, substances being generally more soluble when hot than when cold. If a hot and concentrated sugar solution is cooled, a point is reached at which more sugar is dissolved than if it were attempted to produce a syrup by dissolution at the same temperature. From this point on there is a tendency for the excess of dissolved sugar to separate and appear in a crystallized form. Upon this fundamental principle the sugar manufacturer depends in endeavoring to put into practice some method or process for obtaining the final sugar from a concentrated juice or syrup.

The first essentials of the problem consist in driving out the water under economical conditions, and this is accomplished in two phases, the first of which is the subject now under consideration, known as evaporation, while the second is known as graining, which is treated under a special caption. With a view to effecting fuel economy numerous efforts have been made during the past hundred years to do away with evaporation. For example, it has been pro-

fact that the caramelization which occurred involved sugar losses, But manufacturers appeared to pay but little attention to them. and numerous pieces of apparatus of the kind were to be found in the European beet-sugar factories. As late as 1870 KNAUER[1] argued in favor of the open-pan mode of evaporation.

In 1813 HOWARD[2] took out his British patent for the evaporating or concentration of saccharine solutions by the application of heat under vacuo, effected by means of the continued action of a pump or other exhausting instruments. Evidently the inventor knew that by evaporating under vacuo saccharine solutions could be boiled at lower temperatures, and consequently without danger of burning the sugar. The apparatus has since that time undergone numerous modifications, which will be subsequently discussed. In the meantime there came to light the discovery of a principle which is the basis of the important economical progress realized, namely, the multiple-effect evaporation, which was a marked departure from the old mode of single effect. Through this innovation it was possible to evaporate with one kilo of steam several kilos of water. PÉCLET declares that PECQUEUR was the inventor of the idea, other authorities that to RILLIEUX should be given the full credit. Numerous other modifications applied to evaporation and the various phases of sugar extraction with the view to caloric economy, such as reheating, have resulted in important savings as compared with the obsolete modes.

Quantity of juice to handle.—After the juice has been epurated it must be concentrated in order to crystallize. The volume of saccharine juice to be handled depends upon the size of the plant. For a factory working by the dry-defecation method, the volume of juice obtained is estimated in the following manner: Suppose that 2 kilos of lime have been used for every 100 kilos of beets sliced.

Drawing from diffusion, about 105 liters	110.0 kilos juice
Sweet water from scum and filter presses, 125 per cent of the 8 per cent of scums	10.0 kilos
Various waters of condensation	2.0 kilos
Total	122.0

[1] LIPPMANN, Entwicklung, 150, 1900.
[2] Sugar Specifications, No. 3754, p. 19, 1871.

In factories defecating with milk of lime, the lime consumption is always slightly higher, and consequently the volume of sweet water is greater. As a general thing there is not a sufficient quantity of these waters for the lime slaking, and, such being the case, factories working under the supposed circumstances should allow at least 125 kilos of juice for 100 kilos of beets sliced. The diffusion juice drawn from the battery containing 12 to 13 per cent of sugar will give in defecation tanks a juice containing 10.5 to 11.5 per cent of sugar. In the average factory, slicing 500 tons of beets per diem, there must be concentrated daily 625,000 kilos of juice, while in the larger plants where 1000 to 2000 tons of beets are sliced in the twenty-four hours, 1,250,000 or 2,500,000 kilos of juice are to be concentrated.

Limit of concentration.—Fresh beet juices from the diffusion battery, which test 12° to 13° Brix (6.8° to 7.4° Baumé), are concentrated in evaporating appliances so that they test 60° Brix (33° Bé.), about 80 per cent of the water being thus eliminated. In beet-sugar factories, where the heating surface of the multiple effect is too small or has a very limited efficiency, the concentration is 50° Brix (27.7° Bé.) and even less, evidently at a loss of steam and an increased cost of fuel. The evaporation, under satisfactory circumstances, should be so arranged as to allow a concentration of not less than 55° to 60° Brix. Experience shows that it is not desirable to attain 65° Brix, as concentrating juice in excess of that limit increases the difficulties of graining in the pan, and also crystals may be formed in the pipes of the evaporator, which occasionally results in clogging. In some special cases there is every advantage in not pushing the concentration of the syrups beyond 22° Bé. It has been shown that sugar extracted from syrups which have not been concentrated beyond a certain limit possess special characteristics. On the other hand, there can be no possible reason why an expert should not obtain a superior sugar from very concentrated juices.

Upon general principles it may be said that the degree of concentration depends upon the evaporating power of the multiple effect used. The operation of water elimination may be continued in a vacuum pan; but, as explained under another caption, it is vastly more economical to carry the evaporation as far as possible in the multiple effect.

Outline and description of the evaporators. — In order to evaporate a large volume of juice, a systematically combined

apparatus must be used. The shape of these varies greatly, but generally they consist of large closed receptacles, either circular or rectangular, at the bottom of which is the tubular cluster in which the juice is heated by steam, while on top there is a large evacuating pipe for the liberated vapors. A multiple effect is said to be vertical or horizontal according as the tubes in its interior are vertical or horizontal. These tubes are tightly held in tube plates, which are either round or rectangular, depending upon the type of apparatus. In the vertical evaporating effect the juice boils in the interior of the pipes, while in the horizontal evaporators the juice boils outside the pipes.

Efficiency.—The efficiency of an evaporating apparatus depends upon numerous factors, nearly all of which are now known, the theory and practice of which within reasonable limits agree. The efficiency of an evaporating appliance should be considered from a practical point of view, but this is frequently overlooked, as, when the question of selecting one of two evaporators arises, the basis of purchase is generally the area of heating surface. This is misleading, for one square meter in one case may give better results than two square meters of another apparatus. The first mentioned is certainly the most desirable. Upon general principles it may be said that the efficiency of an evaporating appliance has nothing whatever to do with the economy of heat of the system of evaporation taken as a whole. The latter is based upon the composition and rational combination of the different parts of which it is made up. The efficiency of the parts, taken separately, does not as a rule enter into the consideration when purchasing an evaporating appliance, yet they play a most important rôle when considered collectively.

Under all circumstances every effort should be made to get the best possible practical results from the apparatus used. One may obtain a satisfactory efficiency by simple modes, and obviate the expensive alterations otherwise incurred when it is desired to increase the evaporating capacity of an existing apparatus, by applying certain principles which will be subsequently explained. A thorough study of the means of accomplishing this result, in either a vertical or a horizontal evaporator, as given by CLAASSEN and other authorities, is evidently of great importance. The first facts to be thoroughly understood relate to the changes which occur when a liquid is boiled with steam acting through a metallic medium.

Heat transmission through metallic surfaces.—In all appliances used for evaporating saccharine solutions, there is, on the one hand, the vapor or steam for heating, on the other, the juices to be concentrated, and these are separated by a metallic surface which may be supposed to be vertical. On one side water will continuously condense along the surface. The condensed liquor will flow over its surface, forming a layer of a thickness varying with the temperature, which has a direct influence on the viscosity of water. This layer renders the heating surface partly inactive. Heat passes through the inactive strata of water and the metallic surface, and then finds a new layer of inactive water which is adhering to the other side of the heating surface. It may be admitted that the same factors hold good for either side of the metallic surface. Furthermore, it may be assumed that there is always a certain area of the surface rendered inactive, by its contact with the steam about to be formed on the side containing the juice. This space is very small, as the bubbles have only one point of contact with the surface. On the other hand, it has been asserted that the bubbles are not formed on the heating surface but in the inactive strata, and even in the layers which are comparatively far from the metallic surface, and which have very much less conductivity than the metal itself. Fortunately the nactivity under consideration is only comparative; otherwise the evaporating efficiency per degree of fall of temperature and per unit of surface would be very small.

Factors influencing heat transmission.—While in all the arguments that follow, it is supposed that only a single effect is under consideration, they hold good for each of the compartments of a multiple effect, separately considered, as a simple effect in which, for economical reasons, the heat contained in the vapors from the preceding apparatus is utilized. In the case of the simple effect, the main points to be considered are the quantity of water that will be evaporated per unit of area of heating surface in the unit of time, and the conditions under which the heating surface will transmit the greatest possible amount of heat. This is generally called the coefficient of transmission.

The most desirable construction may be determined upon by taking fully into consideration the various facts, given herewith, relating to transmission of heat. Claassen says this transmission of heat from steam to the boiling liquid increases with the following conditions:

When the liquid circulates rapidly over the entire length of the heating surface;

When the level of the juice is low, and consequently the pressure upon the heating surface is least;

When the steam used for heating circulates rapidly along the heating surface;

When the condensed water is rapidly and thoroughly carried from the heating surface;

When the air in the heating compartment is thoroughly removed;

When all calcareous and other deposits are thoroughly removed, so as not to interfere with a satisfactory transmission of heat;

When the liquid has very little viscosity;

When the juice is hottest, and consequently when the pressure under which it boils is greatest;

When the fall in temperature between the heating surface and the boiling juice is greatest.

Certain authorities, among them JELINEK, declare, furthermore, that heat transmission is in direct proportion to the specific heat of the liquor being evaporated. To this may be added the influence of the conductibility of the metal, which depends upon its heating surface and its thickness.

Influence of the circulation of juice.—As has been previously pointed out there is always along the heating surfaces a thin inactive strata of liquid caused by adhesion and viscosity. This thin layer of juice, in contact with the metal, will rapidly rise in temperature, but, as the water is a poor conductor of heat, the caloric will have difficulty in penetrating this thin medium in order to influence the next zones of liquid. Consequently, in the heating of a metallic surface these difficulties must be overcome in order to transmit the heat to a large volume of liquid. These conditions would no longer exist if it were possible to compel the liquid molecules to be constantly renewed along the entire surface, and several means of producing the requisite circulation and renewal have been proposed. According to AUSTIN[1] the resistance offered by these layers of liquid to the passage of heat may be compared to that of an iron plate of 1.2 to 2 cm. in thickness. If the liquid is thoroughly agitated this may be reduced to 0.75 cm. iron resistance.

The influence of the velocity of the circulating juice upon the

[1] Z., 53, 493, 1903.

coefficient of heat transmission is shown in the PORKONY[1] experiments made in closed reheaters.

Reheaters.	Velocity of Juice per Second.	Coefficient (Cal. for 1 Minute 1° C. and 1 Sq. M.).
	Meters.	Calories.
a	1.29	8.15
a	1.35	16.25
a	1.523	17.71
c	1.29	22.17
b	1.53	33.18

Experiments with water circulating in a copper tube of 1 mm. thickness, 1 cm. diameter, and 31.4 cm. in length, heated with steam at 100° C. at different velocities, give the following figures:

Velocity of Water.	Coefficient.
0.10 m. per second......	1.40
0.20 " " "	2.30
0.30 " " "	2.55
0.40 " " "	2.70
0.50 " " "	2.86
0.60 " " "	3.02
0.70 " " "	3.18
0.80 " " "	3.33
0.90 " " "	3.48
1.00 " " "	3.64

Efforts have been made to renew the particles of liquid upon the metallic heating surfaces by simple mechanical means, but in most cases the circulation due to boiling has been depended upon to produce motion in the liquid mass. The motion in the larger liquid veins in the juice itself is termed *circulation;* when the motion refers only to the film directly in contact with the surface, it is called *ruissellement.* When water has not yet boiled, its resistance corresponds to iron of 10 cm. thickness; when agitated the resistance is reduced to 1 cm. The lower the temperature of the water to be boiled the greater will be the resistance to heat transmission.

Influence of height of juice.—The height of the juice has a most important influence upon the efficiency of evaporating appliances. Some years ago it was thought necessary, when using the vertical apparatus, to keep the level of the juice sufficiently high to completely cover the upper tube plates, that is, at a height at least equal

[1] B. Z., 21, 169, 1896.

to the length of the tubes, or 1.25 to 1.5 meters. The juice was also kept well above the tubes in the horizontal evaporators. The greater the height of the liquid column resting upon a heating surface the greater will be the pressure, and consequently the higher will be the temperature necessary for the boiling of the liquid.

If the hydrostatic pressure only is considered, there should be an appreciable difference in the boiling temperatures of liquids at the top and bottom of evaporating appliances, but such is not the case. Two thermometers placed one beneath and the other above the tubular system will record identical temperatures, and this fact in no way contradicts the theory just mentioned, as the motion of the juices in the apparatus is so swift that the portion which is superheated at one spot near the heating surface will mix with the general turbulent juice as soon as it abandons, in the form of steam, the excess of heat it has received, and thus a thermometer will register the same temperature throughout the compartment. However, where the juice comes in direct contact with the heating surface, it is under the influence of a certain pressure; the steam bubble is formed, and the temperature of the liquid is higher than that of the whole mass of juice, at least this is true during the formation of the bubble. This excess of temperature corresponds to the excess of pressure—otherwise no steam would be generated. The difference of temperature between the steam used for heating and the saccharine liquor falls when the pressure of the juice is increased, and, as the evaporation is proportionate to the fall of temperature, the efficiency of an evaporating appliance decreases with an increase in the height of the juice's level.

It is important also to make allowance for certain facts frequently noticed by experts, such as CLAASSEN and JELINEK,[1] for example, that the juice does not boil at the bottom portion of the calandria. The juice is cooled when it descends to the lower part of the tubes, and in reality only boils at the top. Notwithstanding the fact that there are no data to prove the theory, it is generally admitted that all portions of a vertical multiple effect have about the same evaporating efficiency.

Influence of the circulation of steam.—Experience shows that the rapidity with which steam will move on a metallic surface has an important influence upon the transmission of heat. SIMIRENKO'S[2]

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[1] D. Z., I. 17, 1142, 1892. [2] SACHS, Revue, 1, 125, 1885.

experiments with horizontal tubes, in which conical wooden sticks were introduced, the section being thus reduced at one end, showed that there resulted an increase in the evaporating coefficient of 20 to 30 per cent. No satisfactory explanation has ever been given of the true cause of this phenomenon, but it may be said that the velocity of circulating steam has an important influence upon the inactive strata of the condensed water upon the tubes on the side of the steam. The transmission of heat depends consequently upon the facility with which the condensed water runs off.

Condensed-water removal.—In the vertical evaporators the vapor or steam used for heating has only a moderate velocity; but, on the other hand, the condensed water rapidly runs off from the tubes. In the horizontal multiple effects velocity may be obtained by clustering the tubes in a special way. The same result will be obtained when the tubes have very small diameters, say about 20 mm. The velocity is not, however, very great anywhere, except where the steam enters the apparatus. The nearer the steam is to the orifice of the water evacuation the less will be its velocity, which will finally become zero.

CLAASSEN says that the condensed water gradually runs off from the horizontal evaporators; but the lower portions are never entirely free of water, except when the steam has sufficient velocity to carry it forward. An amelioration in the vertical multiple effects should be mainly directed to the increase of the velocity of steam; on the other hand, with the horizontal evaporators, the principal object in view should be to more thoroughly carry off the condensed water in the tubes. It is evident that all evaporating appliances, whatever be the design, should be so arranged that water could not possibly accumulate in the tubular cluster, as this would cause a proportionate decrease in the efficiency of the apparatus.

Air removal.—Steam used for heating always contains a certain quantity of air, said to be about 5 per cent of the volume of fresh water employed in feeding the boilers. When the vapor used is the outcome of juice boiling in another compartment of the multiple effect, it will necessarily contain other gases that have been liberated during the boiling of saccharine juices. These gases are ammonia and carbonic acid, the outcome of a continued contact of lime and alkalies with the albuminous substances which have not been removed during the previous epuration. When the pressure in the heating chamber is less than the exterior atmospheric pressure,

outside air frequently enters through the cracks. The influence of the gases under consideration is variable. Ammonia which is lighter than air tends to collect on the upper part of the heating tubes. On the other hand, air and carbonic acid being heavier tend to settle in the lower portion of the heating chamber. As the steam used for heating enters the apparatus at a velocity of several meters per second it acts as a mixer, and thus overcomes the possibility of inactive portions remaining in the evaporating compartment. CLAASSEN says that generally in discussing these questions ammoniacal vapors are mentioned as non-condensable gases, notwithstanding the fact that the greater portion of the ammonia is absorbed by the condensed water.

There are certain spots where the motion is less and where the gases are forced out. Experience shows that in vertical evaporating appliances, brass tubes are eaten away only at their upper extremities, from which fact it is concluded that all the gases collect on top. In all cases, if the non-condensable gases are not removed, they will collect in the steam chamber, and gradually increase in volume, reaching such proportions that the heating surface is lost for the condensation of vapors and consequently for the transmission of heat.

The corrosion of the tubes just mentioned could not be caused by the ammonia alone; this phenomenon is rather an oxidation due to the presence of air, followed by a solution of the oxide of copper by the ammonia, leaving a fresh surface to be attacked by the oxygen. From what has been said the importance of a complete and continual evacuation of these gases is self-evident, as ammonia and oxygen are always simultaneously present and must necessarily corrode the brass and copper tubes, if allowed to collect for any considerable time in one special spot.

It is to be noted, however, that all the phenomena existing during corrosion cannot be attributed to chemical action. According to BATTUT[1] this eating away of the tubes in the central and remotest parts of the cluster extends only for a few millimeters beneath the tube plate, and it is mainly those tubes which are placed near the entrance of the steam that are corroded, the entire height of the latter in that portion facing the steam being affected. Other parts of the tubes are sometimes corroded, but this is an exception rather than the rule. Some seek to explain the corrosion

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[1] S. I., 20, 411, 1892.

by a galvanic action between the copper tubes and the iron-tube plates. It seems reasonable to suppose that there is a mechanical cleansing action due to the steam, the fresh surfaces being then more readily attacked by the ammonia. The following analysis of GAWALOWSKI[1] apparently shows that the tube destruction by the non-condensed gases is in reality an oxidation of the metal.

	Per Cent.
Copper oxide	48.7
Zinc oxide	45.33
Calcium oxide	0.35
Magnesia	traces
Water	3.60
Ammonia, fatty substances, etc.	1.81

Another deposit, frequently found alongside the vapor entrance upon the tubes, consisted, according to STIFT'S[2] analysis, of 48.55 per cent of copper oxide and 36.31 per cent of zinc oxide.

Influence of the metal's conductibility.—The rapidity with which metals conduct heat is very variable. If 100 represents the conductibility of silver, which is the best-known conductor, other metals, according to WIEDMANN and FRANZ, have the following conductibility: Silver, 100; copper, 74; brass, 23; zinc, 19; tin, 15; iron, 12; and lead, 9. The JELINEK[3] data which he uses in his calculations are very different from these. According to this authority brass containing 70 per cent of copper will transmit the same amount of heat as copper, while for iron the conductivity is very much less. The coefficient of heat transmission is inversely proportional to the thickness of the metal, that is to say a 2 mm. thickness of metallic plate will allow, under the same conditions, exactly one-half as much heat to pass through it as a plate 1 mm. thick.

Influence of deposits.—Evidently a metal transmits through its surface the maximum amount of heat when the surface, without being perfectly smooth, presents the maximum contact with the liquid. Numerous experiments show that a polished surface always results in little or no loss of heat through radiation, and this fact is not to be neglected when comparing it with direct transmission through contact.

The nature of the deposits varies very much inside and outside of the evaporating tubes. The heating vapor used in multiple

[1] D. Z. I., 4, 278, 1879. [2] Oe.-U. Z., 30, 734, 1901.
[3] B. Z., 19, 158, 1894.

effects is from the exhausts of engines, and will deposit upon the surface of tubes a layer of variable thickness of mineral oil, etc., which has remained suspended from the lubricating substance used in the engines. This is a non-conducting medium and consequently causes a reduction in the coefficient of heat transmission.

On the other side of the heating surface the formation of deposits may be more readily explained. They are due to neutral carbonates, generally the outcome of excessive carbonatation, the bicarbonates being decomposed under the influence of the heat. To these must be added the insoluble salts and oxides, the insolubility of which increases with the concentration of the juice.

Scums adhering to the filtering cloths frequently contain considerable alumina silicate, which may be attributed to the lime used in defecating the raw juices. Experiments have been made to determine the degree of solubility of ferric oxide, alumina, and silica contained in quicklime, when in hot sugar solutions. It was found that as soon as the alkalinity was lowered to between 0.15 and 0.07, the percentages of lime and alumina were also less. The solubility of silicic acid remained nearly constant at variable alkalinities. When a sugar solution is left under low temperature for a considerable time, it was found that the percentage of ferric oxide and alumina dissolved is greater than when in a hot sugar solution. During carbonatation the oxide dissolves and, introduced by the lime used, will partially precipitate, incrust the evaporating appliances, and clog the filtering cloths during filtration. The following analyses show the composition of the principal deposits in multiple effects on the surfaces exposed to the juice. BIARD'S[1] analyses of these deposits in the several compartments showed the following:

BIARD'S ANALYSES OF THE DEPOSITS IN MULTIPLE EFFECTS ON SURFACES EXPOSED TO THE JUICE.

Constituents.	First Compartment.	Second Compartment.	Third Compartment.	Fourth Compartment.
Water and calcic sulphate	1.44	2.14	2.80	4.87
Organic substances	25.29	22.08	18.00	13.64
Potassic chloride	0.60	0.49	0.76	0.90
Calcic sulphate	5.43	8.07	10.60	18.37
Phosphate of lime	49.68	52.67	56.30	40.09
Phosphate of magnesia	7.76	2.67	0.22	0.03
Organic lime	2.37	3.46	3.39	1.90
Ferric oxide and alumina	1.98	3.23	1.68	2.51
Silica	2.97	1.95	1.63	13.49
Losses	2.48	3.84	4.62	4.20

[1] BEAUDET, Traité I, p. 451.

In other analyses as much as 30 per cent of silica has been found. VERSCHAFFEL and also certain Austrian chemists have frequently called attention to the fact that the deposits in evaporating appliances contain enormous quantities of calcium oxalate, precipitated during evaporation. This precipitate is very insoluble, and at first it may seem strange that it was not eliminated during epuration and deposited on the filter presses, but the characteristic possessed by a large number of salts, especially lime salts, of precipitating slowly from their solutions must not be overlooked. VON LIPPMANN [1] calls attention to malonic acid in these deposits. In some Hawaiian Island cane juices [2] citric acid was found in the deposits. Later this same compound was detected in Austrian multiple effects.

Most fresh beet juices, when evaporated, will give a calcareous deposit when they are boiled, filtered, etc.; the results are within reasonable limits always the same. The lime deposits have but little influence on the actual efficiency of the multiple effect unless in excess, but these incrustations increase and must be removed. Considering the different conditions under which the various compartments of a multiple effect are working, it is evident that the amounts of deposit which they contain will vary. If the operations of defecation, carbonatation, filtration, etc., have been conducted in accordance with the principles determined by experience, the deposits in the first compartment are comparatively small, but the reverse is the case in the last compartment, the amount of the deposit depending upon the percentage of slightly soluble calcic salts in the juice being treated. On the other hand, if the second carbonatation has been in any way neglected, or if it has been conducted at a temperature not suited to the operation the calcic deposits in the first compartment will be large. The deposits in the first compartment are generally the outcome of particles of scum which find their way into the apparatus at the same time as the juice, while the deposits in the last compartment are the outcome of the calcic salts dissolved in the juice and precipitated after the evaporation of the greater part of the water.

These deposits are all poor conductors of heat. According to DESSIN [3] calcareous deposits have one hundred times less conducting power than brass used in heating receptacles. It is to be noticed

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[1] Oe.-U. Z., 10, 386, 1881. [2] D. Z. I., 19, 1274, 1894.
[3] Bull. Synd., 13, suppl., p. 15, 1893.

that in these compounds there is a great variation in conductibility. Evidently when such deposits are porous, as with carbonate of lime, the resistance offered to heat transmission is lessened. On the other hand, the greatest resistance is reached with alumina silicate, the deposits of which are smooth and hard. These few examples suffice to show how very complicated and varied is the whole issue of heat transmission in a multiple effect, yet the economical and efficient working of the apparatus depends upon the maximum degree of this transmission.

According to PECLET one square meter of brass should allow 103 kilograms of water to evaporate per hour and per degree of the fall of temperature. HORSIN-DÉON[1] says that practical experiments show this to be but 4 kilos and in some special cases only 1.5 kilos. This authority further points out that deposits have an objectionable influence on the composition of saccharine juices with which they come in contact, and may sometimes form a nucleus for fermentation.

Influence of specific heat of juices.—It is interesting to recall the significance of the term *specific heat*. The proportion existing between the number of calories necessary to raise the temperature of a given liquid one degree centigrade and the number necessary to raise water that amount is known as specific heat. For example, to raise one degree centigrade the temperature of a substance having a specific heat of 0.5 will require one-half the number of calories necessary to raise the temperature of water one degree. JELINEK reached the conclusion that the coefficient of heat transmission depended upon specific heat. In the experiments made the curve of specific heat of the solutions corresponded absolutely with that of the coefficient. In the CLAASSEN[2] experiments with solutions of different densities this similarity no longer exists, and this authority claims that the coefficient depends entirely upon the viscosity and that the specific heat has very little influence upon the transmission. This question is open to discussion and would lead us beyond the scope of the present writing. The specific heat of sugar solutions is as given in the table on page 17.

CURIN[3] claims that from a practical standpoint KOPP's data are preferable. It must not be forgotten that foreign substances contained in saccharine juices have a very low specific heat.

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[1] HORSIN-DÉON, Traité II, 1, 538, 1901. [2] C., 4, 795, 1896.
[3] Oe.-U. Z., 23, 988, 1894.

SPECIFIC HEAT OF SACCHARINE SOLUTIONS.

Brix.	Kopp.	Marignac.
10°	0.9342	0.942
20°	0.8684	0.884
30°	0.8026	0.826
40°	0.7368	0.768
50°	0.6710	0.710
60°	0.6052	0.652
70°	0.5394	0.594
80°	0.4736	0.536
90°	0.4078	0.478

Influence of viscosity of juices.—The viscosity of the juice has considerable influence upon heat transmission in a multiple effect. As the juices to be evaporated have a purity of 90 and even more, they contain proportionately very much more sugar than non-sugar, and the influence of the latter upon the viscosity of the beet juices is so slight that the actual composition of the non-sugar need not here be considered. Juices of the same concentration have practically the same viscosity, but this viscosity rapidly increases with the concentration and consequently with the sugar percentage. Concentrated juices are more viscous than defecated juices, and this renders the efficiency of the last compartment of the multiple effect less than that of the first compartment.

Influence of fall of temperature.—A fall of temperature means the difference that exists between the heating medium and that heated, and in the case of evaporation it means the difference between the temperature of the steam used for heating and that of the saccharine juice being concentrated by boiling. Numerous experiments have shown that the coefficient of heat transmission is proportional to the fall of temperature. CLAASSEN's experiments have demonstrated that for an equal fall of temperature, per number of degrees, the heat transmission was greater when the work was done at a high temperature. For example, the coefficient of heat transmission for 1° C. of fall of temperature will be much higher above 100° than below that temperature. Consequently it will be less in vacuo than under pressure.

There is yet a very important issue to consider under the caption of Heating Surfaces, and that is the conditions under which steam should be used. As a rule authorities agree that the steam sent to multiple effects should be as dry as possible, as the water held in suspension is that much waste. HORSIN-DÉON advances the theory that moist vapor is more difficult to condense than dry.

Numerous authorities have for several years past claimed that superheated steam cannot be advantageously used in multiple effects, that it acts like gases, will not condense on heating surfaces, and will consequently abandon very little heat. MALANDER states that in some boiling experiments with saturated steam and with superheated steam at 0.7 of an atmosphere and at 250° C. comparatively little advantage one over the other was observed, and that no difference could be noticed in the efficiency of the appliance used. No data were determined, but it is claimed that these experiments demonstrated beyond cavil that superheated steam may be advantageously used for this purpose.

All these conditions for a satisfactory transmission of heat should be realized with the simplest possible devices, so that an evaporating appliance may be easily cared for and operated. It should furthermore offer certain guarantees that sugar losses will not occur, and should be of a reasonable price. Of all the essentials relating to the evaporating appliances used in sugar factories, the most important is the simplicity of construction and facility of handling. As these appliances work night and day, and in most cases are stopped only on Sunday for repairs and cleaning, all combinations which are likely to cause perturbations in the work or to need exceptional care should be rejected. The standard types of evaporators may be handled by the average workman.

CHAPTER II.

EVAPORATORS.

Shape of the apparatus.—The early evaporating apparatus, like that first combined by RILLIEUX (Fig. 2), had the shape of a locomotive boiler. It consists of a horizontal boiler, A, with an

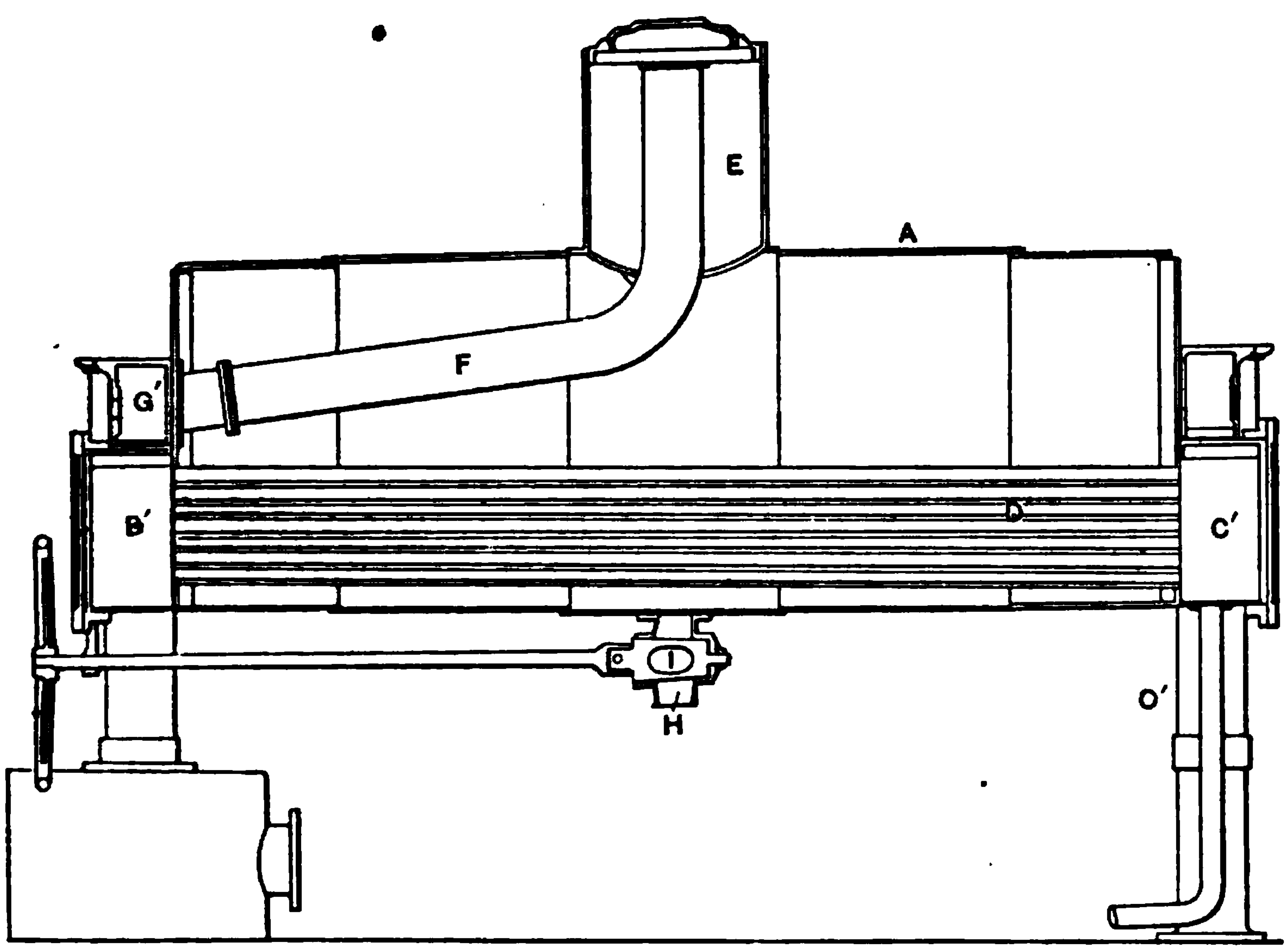

FIG. 2.—RILLIEUX's Horizontal Evaporator.

upper dome, E. There is a series of tubes, D, at one end of which is the chamber, B', into which the steam enters, and at the other the chamber, C', into which the condensed water flows. The juice to be concentrated is on the outside of the tubes. The resulting vapors rise into the dome and subsequently pass into F, and then through G' into the next compartment. The apparatus was well suited for the evaporation of cane juice which left little or no deposit, but was certainly not adapted to beet juice yielding

calcareous incrustations. Later RILLIEUX combined an apparatus known as triple effect which as a whole does not differ from that now used. The first vèrtical arrangement was then built by ROBERT.

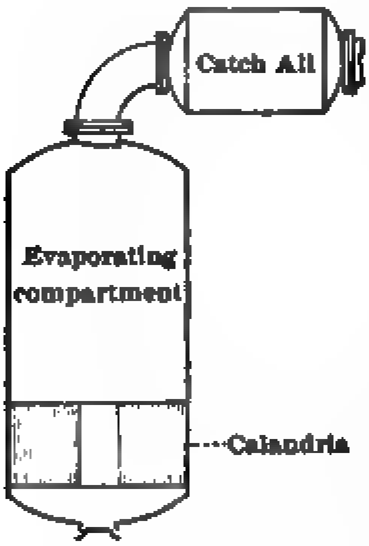

FIG. 3.—Standard Vertical Evaporator.

These early triple effects were followed by numerous variations, the principle, however, always remaining the same. Both the vertical and horizontal effects underwent a series of improvements or changes simultaneously. All the vertical types are cylindrical in shape (Fig. 3). The height of the calandria varies with the builder, but the height of the evaporating compartment, including the calandria, should not be less than five meters, so as to obviate the entrainment due to projection of the saccharine juices. These apparatus are sometimes made of cast or sheet iron, German builders appearing to give preference to the former.

One of the most original arrangements is the PATTEN (Fig. 4) multiple effect, in which the compartments consist of thin sheets of metal, such as copper or lead, the sides being held in position by massive brickwork, which makes an excellent non-conductor. From its general appearance the combination must be expensive and no case has been found of its practical use, but it is interesting on account of its originality.

The horizontal evaporators vary greatly in shape, the original RILLIEUX arrangement having been kept in the ADERS and many other standard ap-

FIG. 4.—PATTEN Evaporator.

pliances. This shape had certain objectionable features, owing to the entrainment of the juice during boiling. The first change made was to raise the evaporating chamber. In the SIMIRENKO effect the tubular cluster was in the shape of a cube, while the high evaporating chamber was cylindrical. WELLNER and JELINEK gave their horizontal evaporator the shape of a box with slightly rounded upper corners. In this arrangement the tubular cluster should be nearer the bottom than shown in the drawing (Fig. 5). Whatever be the type of construction there is

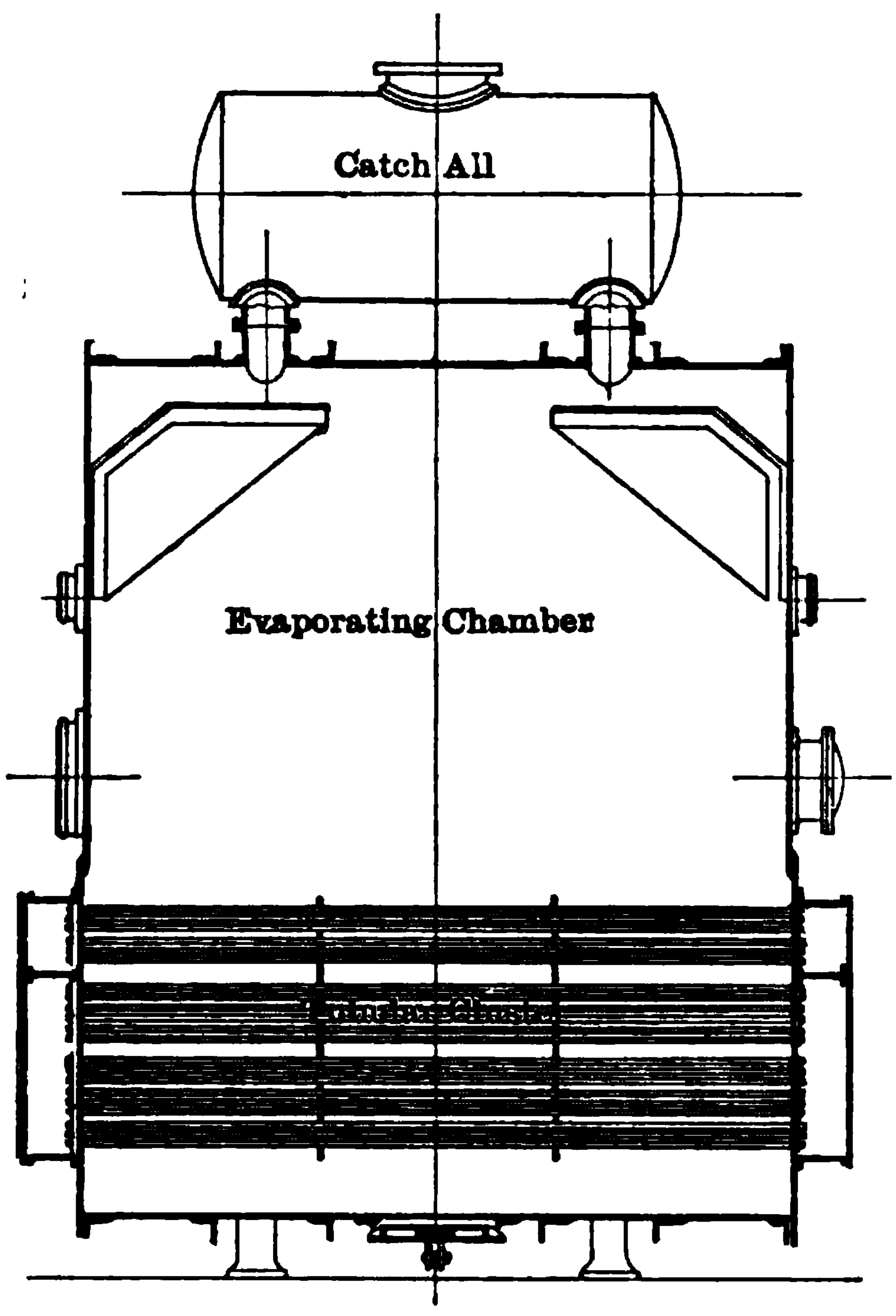

FIG. 5.—The WELLNER and JELINEK Evaporator.

always an upper opening sufficiently large to permit an easy escape of the liberated vapors through boiling, the manhole at the bottom being adapted to the requirements.

Heat isolation.—To prevent loss of heat through radiation it is essential to cover the outside of these evaporators with suitable non-conductors. It was even proposed by MARTIKKE[1] to paint

[1] Oe.-U. Z., 14, 183, 1885.

the interior of the evaporating chambers with some substance which would not be attacked by the juices. The large pipes conducting the vapors from one compartment to another are responsible for the greatest loss of heat. They must be covered with some non-conductor, which should be light, incombustible, and sufficiently strong to stand some wear and tear. In the PASQUAY[1] experiments are given the conductivity of various protective substances used as non-conductors, silk waste being apparently the best. The various conductivities are as follows:

Silk	0.045 to 0.048
Cow-hair felt	0.057
Cork shavings	0.073
Chopped turf	0.073 to 0.0997
Kieselguhr	0.077 to 0.144
Leroy's mixture	0.089 to 0.125
Knock's mixture	0.090 to 0.240
Slag wool	0.101
Grunzweig and Hartmann's (Kieselguhr)	0.122
Einsiedel's mixture	0.139

In these experiments it was noticed that steam at 135 C., circulating through pipes with the temperature of the ambient air at 13.5 to 16 C., would condense, per sq. m. and per hour, 2.972 to 3.087 kilos. In the same pipe covered with 25 mm. of a non-conducting substance, such as silk, the condensation was only 0.446 kilos. It is to be noticed, however, that these silk wastes are very seldom employed in beet-sugar factories. On the other hand, felt and cow hair are very much used in Germany, especially for covering vacuum pans and reheaters connected with the evaporating apparatus. These materials might also be profitably used on the evaporating compartments, especially the last of the series, but it is not advisable to use them for the first compartment, where the pressure within is greater than the atmospheric pressure. Under these conditions the hair non-conductor would soon dry and burn. Under no circumstances should this non-conductor be used in pipes through which live steam circulates. The non-conductors generally employed for evaporating appliances consist of different mixtures of lime, clay, and cow hair, used in layers about 25 to 50 mm. in thickness. Wood lagging of pitchpine, etc., adds to the general appearance of the apparatus and also acts as a non-conductor.

[1] HAUSBRAND, Evaporating, p. 206.

Heating surface.—The heating surface of evaporating appliances consists of iron, steel, or brass tubes, which are sometimes tinned. Experience shows that brass is the best conductor of all usual metals, but its ready corrosion by ammonia is one of the objections to its use. It remains to be shown whether the advantage of its conductibility does not compensate for the disadvantage of corrosion, as compared with steel or tin-lined brass tubes; the latter are not only poorer conductors but of thicker metal. However, these steel-drawn tubes are in considerable vogue in Germany, and their use has been highly recommended by ANDREÆ.[1] They were used by HECKMANN and ADERS[2] as early as 1852. Copper is seldom used for the purpose.

The transmission of heat through metals differs very much, but this difference does not play an important rôle when the surface of the tubes is clean. The kind of surface is also important, not only where the juice comes in contact, but also on the side where the steam circulates. From this point of view, brass is preferable to iron, as the surface of iron tubes after a very short time becomes covered with rust, which cannot be removed, and proves to be a poor conductor of heat.

The thickness of the tubes must also be considered: iron, for example, does not conduct heat as readily as brass, and is used of an extra thickness. Experience seems to show that the best results are obtained with brass tubes 2 mm. in thickness. If less than this they would not be strong enough to resist the pressure of the circulating steam. HECKMANN[3] has proposed to have the extremities of the heating tubes rather thicker than the sides, the advantage being that there is thus far less danger from leaks, etc., but for some reason the idea has not found its way into general practice. In Fig. 6 is shown the position of the heating tubes in the tube plate, T. The diameter of the heating tubes varies from 20 to 50 mm. Generally this diameter is greater for vertical than for horizontal clusters. For the latter the standard used is about 25 mm., while for the vertical it is 45 mm. One of the advantages of small diameters is that a greater number may be placed in a given area, and heat transmission is necessarily proportionately greater. But when the juice is to boil

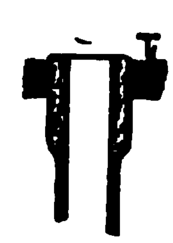

FIG. 6.—HECKMANN'S Reinforced Tube.

[1] Z., 15, 772, 1865. [2] Z., 5, 60, 1855.
[3] STOHMANN, Handbuch IV, 365, 1899.

in the interior of the pipes, as in vertical effects, the resistance offered to the escaping steam is inversely proportional to the square of the section of the tubes. This explains why most of the arrangements for ruissellement have been abandoned.

Still another objectionable feature of tubes of small diameter is that it is almost impossible to hold them tightly in position on the tube plate. Numerous arrangements have been invented which in a measure overcome the difficulty. For example, Karlik[1] proposed the use of tubes of small diameter held together by suitable sleeves so as to form a cluster in the tube plate. The apparatus has thus as many clusters as it would otherwise have had tubes. This arrangement has never been used to any great extent and is better suited to horizontal than to vertical evaporators. The length of the tubes is limited in the case of vertical effects, for it must not be overlooked that the greater the height of the juice in these tubes the lower is the boiling. For horizontal evaporators no account need be taken of this fact; on the contrary, the longer the tubes are for a given heating surface and width of apparatus the lower may be the level of the juice being evaporated. In vertical effects the tubes are from 1.25 to 1.50 mm. in length. The objection to having them shorter, with all the advantage they would offer, would be the necessity of increasing the diameter of the calandria and consequently the evaporating chamber.

Tube plates of vertical evaporators.—The tube plates are generally circular for vertical multiple effects. There are two, one keeping firmly in position the upper and the other the lower end of the tubes. The lower plate is very near the bottom of the evaporating chamber. The steam circulates between the two plates on the exterior of the tubes. It is of secondary importance from the standpoint of heat conduction what metal the tube plate is made of, as the space remaining between the holes through which the tubes penetrate, is comparatively small and may be neglected. Some builders prefer using bronze rather than iron tube plates, with a view to overcoming any possible galvanic action due to the difference of metals in contact.

The most important in the construction of a tube plate is its diameter, which rarely exceeds three meters, and even that dimension offers various difficulties in the proper adjustment of all the joints of the tubes, etc. When these plates are of an exceptional size,

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[1] Oe.-U. Z., 24, 840, 1895.

such as 5.5 meters, as was seen by the writer at the MEAUX (France) beet-sugar factory, they are of bronze and turned on a lathe. When larger than this it is very difficult to turn them and for this and numerous other reasons the diameter of the compartments of a multiple effect is necessarily limited.

The tube plates are generally riveted to the interior of the evaporating compartment. Some machine works, such as CAIL & Co., make independent calandrias, freely suspended and held in position by suitable bolts extending from the top to the bottom of the compartment. The tube plate is readily held in position and may consist of a simple sheet-iron disk. At different parts of the tube plates are smaller bolts which brace the top and lower plates and keep the cluster perfectly rigid.

The tubes are made tight by means of so-called dudgeons which flatten the ends against the holes of the plate and are then removed. There is some difficulty in taking the tubes apart when they need renewing on account of corrosion or for other reasons. MOLINOS and MACHEREZ[1] proposed that they be screwed into the plates and FESL[2] has lately proposed a new device. A bolt, a little longer than the tube, is introduced in the latter from the top. It has a border a little wider than the interior diameter of the tube, and less than the exterior diameter. At the other extremity, above the tube, a ring is placed upon the tube plate, covered by a plate which is held in position by the nut of the bolt. By simply turning the nut, the tubes may be taken from their position.

Horizontal evaporators.—In horizontal evaporators steam is introduced into a cast-iron, rather narrow vertical chamber, which is closed by a suitable door or cover held in position by bolts. This arrangement permits easy access to the end of the tubes. Opposite this door is the tube plate, which is rectangular instead of round. At the other extremity the arrangement is identical, with this difference, that instead of an entrance pipe for the steam, there is an exit for the condensed water. When these appliances are of considerable size, the steam chamber is made in several pieces, placed one beside the other. They may work singly or collectively, so as to receive the steam successively, one after the other, or even to be heated with different kinds of steam.

In the horizontal evaporator of the BRONNE & SIMON[3] type, the

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[1] S. I., 5, 83, 1870. [2] Oe.-U. Z., 30, 772, 1901.
[3] BRONNE & SIMON, Appareil à évaporer, 6, 1872.

steam enters into only one portion of the tubular cluster at a time and then passes successively through the others. It is claimed that the steam thus gives up more readily its latent heat. Mention also may be made of the peculiar tube arrangement of the SIMIRENKO[1] (Fig. 7) evaporator. The tubes in this apparatus are in layers that cross in a perpendicular direction. On each side of the apparatus are chambers, *B*, *C*, *D* and *E*, for steam distribution. The condensed water is removed through the pipes, *m*, *n* and *o*. It is pointed out that the space lost by the heating surface is thus

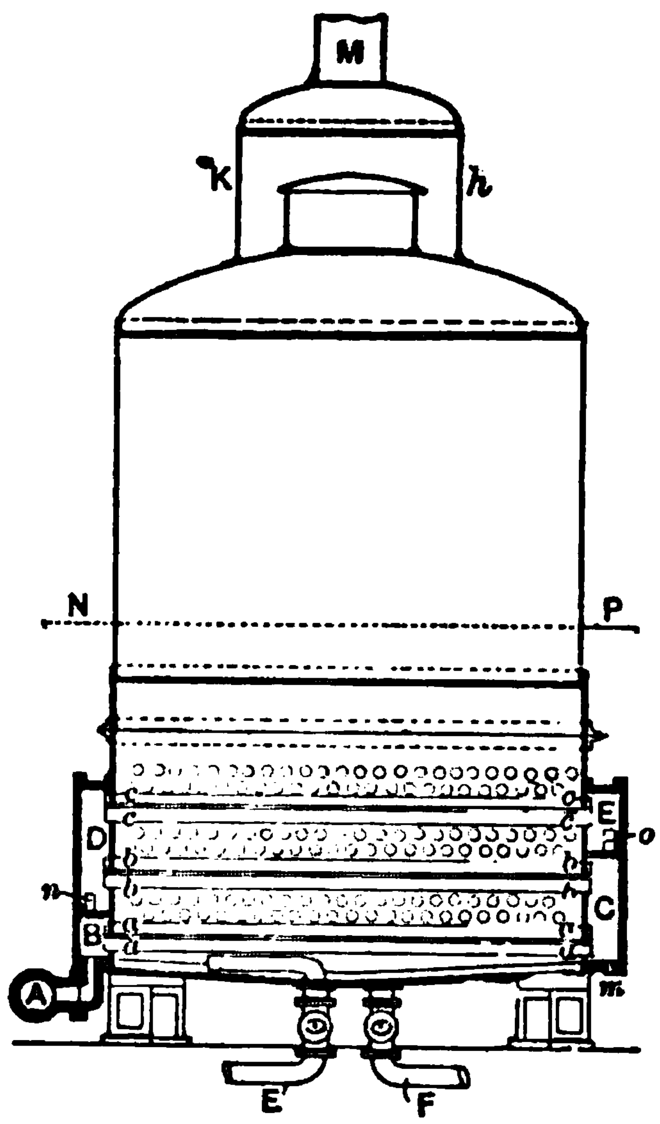

FIG. 7.—SIMIRENKO Evaporator.

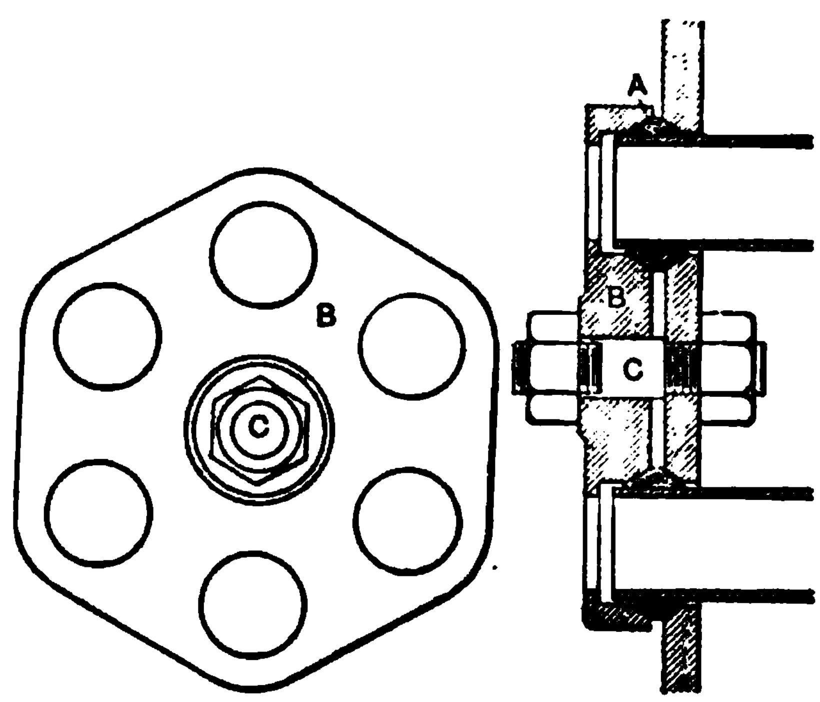

FIG. 8.—ANDREÆ Tube Joint.

reduced to a minimum. The juice enters and leaves the evaporator through *E'* and *F*, Fig. 7.

In the horizontal evaporators the tubes are seldom forced into position upon the plates by the use of dudgeons as previously explained. As a general thing suitable rubber rings are passed over the end of the tubes and subsequently tightened. ANDREÆ arranges the tubes in clusters of six (Fig. 8), and makes them tight by placing rubber rings at the junction of the tubes and tube plates. These are tightly held by a hexagonal disk, *B*, and the bolt, *C*. In the AMBROGEVITCH[2] combination, instead of six there are 36 tubes forming a cluster, and there are 21 groups. It is claimed that

[1] SACHS, Revue, 2, 241, 1888. [2] *Ibid.*, 2, 254, 1888.

this arrangement offers advantages for changing the tubes. In eight hours 756 tubes may be taken out and replaced. Among the interesting and special combinations for tubes may be mentioned the WITKOWITCH (Fig. 9) arrangement, which consists of a cubical box holding the tubes for juice circulation. These tubes cross each other at right angles, and the entire apparatus is submerged in the juice in such a manner that all the tubes are at an angle of 45° with the horizontal. The juice enters at the bottom and leaves on top, so forming a double closed loop in this form: ∞.

FIG. 9.—WITKOWITCH Tube Cluster.

Advantages of different apparatus.—The horizontal and vertical multiple effects each present certain advantages as regards the flow of the condensed water and the velocity of the circulating steam. Suffice it to say that the experiments of HORSIN-DÉON[1] and other authorities show that there is no appreciable difference in the efficiency of the two kinds of multiple effects. The special construction for juice circulation in both cases necessarily produces different incrustations, being in the interior of the tubes in the vertical evaporators and on the exterior in the horizontal type. The cleaning of the vertical tubes is easier and requires less work than the horizontal; but the latter, on the other hand, are more readily placed in position than the former. One of the principal characteristic advantages of the horizontal multiple effect is that it may be built in enormous proportions to meet the requirements of almost any slicing plant. The selection of an evaporating plant should be made only after the size of the factory has been decided, this depending upon numerous conditions, such as environment, the capital at one's disposal, etc.

Juice circulation.—It has already been pointed out that the rapidity with which juice is renewed upon the surface of the heating tubes exerts an important influence on heat transmission. Numerous efforts have been made to bring about a rational circulation of the juice in the evaporator. HALLSTROEM proposed that a large tube of 150 to 300 mm. be placed in the centre of the tubular cluster of the calandria. Under these circumstances the juice could rapidly reach the bottom without contending with steam bubbles, which are

[1] HORSIN-DÉON, Traité II, 2, 618, 1901.

important obstructors in the interior of small tubes, the descending juice being constantly pushed upward by the ascending bubbles. It was supposed that a methodical motion would thus be given to the juice, but experience shows that only a slight increase in the efficiency was effected.

An evaporating apparatus of the ordinary design has a central pipe to allow the overflow of juice from the small pipes, of which the appliances consist, to return to the lower part of the evaporator. Unfortunately in this central pipe there is formed a strata of vapor by the rapid evaporation of the liquid brought about by the steam in contact with its outer surface. Under these circumstances the descending liquor is checked. A new device consists in suspending in the central pipe another pipe of smaller diameter and projecting below the lower plate holding the cluster of small tubes. The space between the two pipes is closed on top, and fresh beet juice to be evaporated is made to circulate in the annular space. While one portion of the juice will be heated, it will nevertheless have a cooling effect upon the juice moving downward in the central pipe. It is interesting to note that this SCHWAGER[1] evaporator has a double bottom in which steam circulates, the object being to force an upward circulation of the juices through the small pipes, and thus increase the evaporating capacity of the apparatus as a whole.

In some cases the juice is directed toward the outer periphery of the tube cluster by having an annular space between the calandria and the outer surface of the apparatus. Mention may also be made of the LWOWSKI[2] combination, in which the whole tubular cluster is slanted so that the juice thus raised in the highest tubes may fall to the lowest. To accelerate the circulation in evaporating appliances ROEHRIG and KOENIG[3] placed another series of tubes heated with live steam in the centre of the tubular cluster, slightly higher than those of the exterior. The juice boils and runs over from the inner to the outer cluster of tubes. Above these central tubes is a sort of disk which prevents violent projections of the juice being concentrated.

TIEDE[4] uses tubes of smaller diameter in the centre of the compartments of a multiple effect to obtain a better circulation of the juice. It is claimed that the heat transmission is increased by this arrangement, and consequently the boiling is more active than

[1] Z., 51, 56, 1901.
[2] N. Z., 35, 132, 1895.
[3] Z., 52, 1063, 1902.
[4] Z., 52, 55, 1902.

it would otherwise be. There is formed a suction of the juice through the tubes of the periphery and from the bottom toward the tubes of smaller diameter. These may be arranged in separate clusters and heated by steam under higher pressure than is necessary for the rest of the calandria.

An arrangement intended to increase the circulation of the juice in the first compartment of a multiple effect consists in the installation of a small vertical reheater, called a circulator, connected with the first compartment, both on top and underneath the calandria. The steam bubbles carry the juice forward and project it over the disk holding the tubes, while the juice enters the circulator at the bottom from the first compartment of the evaporator. The benefit of this apparatus is, however, very doubtful, for the reason that the current of juice brought into the evaporator is just the opposite to that which would have otherwise existed. If, notwithstanding this, the circulator increases the evaporation, it is due to the fact that the heating has been done with steam at high tension, and this is always expensive in sugar manufacture.

Ader[1] proposes to increase the speed of circulation in multiple effects by the use of special pumps or spirals, working in the central circulating pipe. In the horizontal appliances the spacing between tubes or clusters of tubes should be sufficient to permit the juice to find a passage toward the bottom. It may be said upon general principles, however, that the horizontal evaporators are not adapted to forced circulation; although even by the Abraham combination some increase in circulation is obtained (Figs. 10 and 11). Between

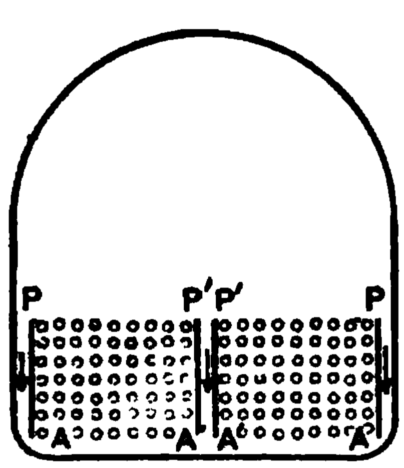

Fig. 10.

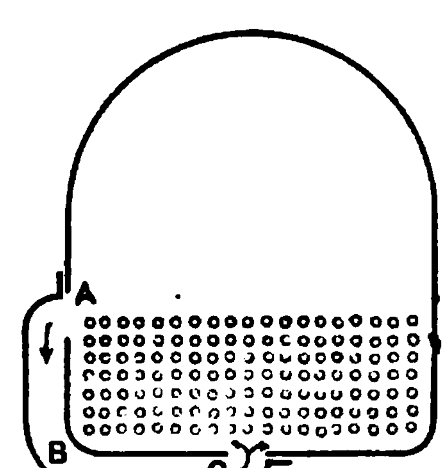

Fig. 11.

Abraham Evaporator.

the tubes is arranged a canal, P, in which the juice descends, or a canal, A, B, C, is placed on the outside of the compartment. In Fig. 11 the circulation is shown.

[1] Jahrb., 26, 71, 1887.

Besprinkling the heating surface.—The importance of having a thin layer of juice on the heating surface of the tubes has already been discussed. It is evident that only that portion of the juice which comes directly in contact with the tubes can store up heat, as the liquid itself, being a poor conductor, is unable to conduct the caloric rapidly through its mass. Efforts have been made to render the film being heated as thin as possible, and this has been accomplished in two ways: either by sprinkling the juice in fine drops, or by regulating the flow so that the layer of juice is very thin over the heating surface. The latter method, which is called ruissellement, has found numerous applications.

MOLINOS and MACHEREZ[1] proposed that the juice be introduced into the multiple effect as a finely divided spray. GOERZ[2] constructed a horizontal apparatus into which the juice is projected in fine drops by means of an injector or a pump. The same idea was carried out by HAACKE and SCHALLEHN by suspending above the horizontal tubes a large receptacle, *S* (Fig. 12), with a perforated

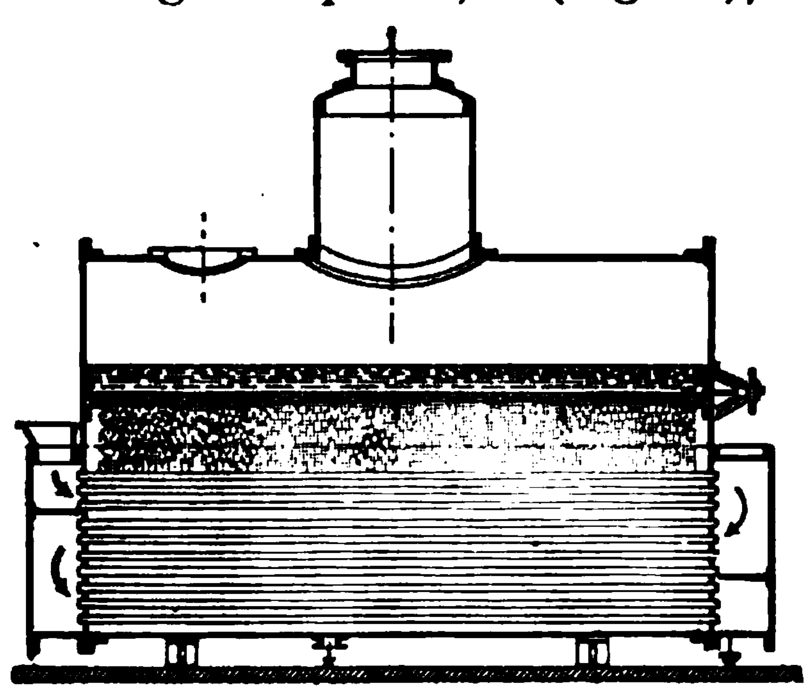

FIG. 12.—HAACKE and SCHALLEHN Evaporator with Upper Sprinkler.

bottom which allowed the juice to filter through, in drops or driblets, upon the tubes beneath. While such methods of ruissellement have been almost entirely abandoned in European beet-sugar factories, in the United States they have been taken up and successfully used in practical work with both the YARYAN and LILLIE evaporators.

Ruissellement.—Even in the very early efforts to extract sugar from the beet the essential conditions for satisfactory evaporation were well understood. To MATHIEU DE DOMBASLE[3] must be given

[1] S. I., 5, 83, 1870. [2] Z., 33, 695, 1883.

[3] DOMBASLE, Fabrication du Sucre, II, 151, 1822.

the credit of having first experimented with ruissellement on a practical basis in 1811. ESBACH[1] says that practical apparatus of this kind were made by MARTIN and CHAMPONNOIS and also at LEMBEEK. The numerous appliances invented since then and abandoned cannot all be mentioned here, suffice it to say that in them the ruissellement was obtained either through gravity, allowing the liquid that is to be concentrated to flow in the interior of the tubes, or by utilizing the ascending force of steam bubbles to displace the thin layers of liquid on the tubes from the bottom to the top.

In evaporating appliances, when the liquid is in thin layers, the heating surface is entirely utilized for the evaporation, and even if the activity is not the same in every portion of the compartment, owing to the uneven distribution of steam, the average coefficient of evaporation is higher than in most other apparatus. The renewing of the liquid is assured in every portion of the apparatus, and however slight the fall of temperature may be in the least-heated part of the apparatus, as the liquid column has no perceptible influence, there will be evaporation in that portion. The whole issue, however, from a practical standpoint goes back only ten years.

Among the first of those who gave this question serious attention was GREINER. His early patent consisted in placing (Fig. 13) over the upper portion of the tubes, r, inverted truncated cone attachments m. Their lower diameter is slightly less than that of the tubes over which they are placed, and the juice running over the tubular plate circulates through the annular spaces thus formed and streams along the inside of the tubes. In another arrangement by the same inventor (Fig. 14) there is no longer an annular space, but the upper conical portion has a series of slits, l, and small holes through which the juice may penetrate.

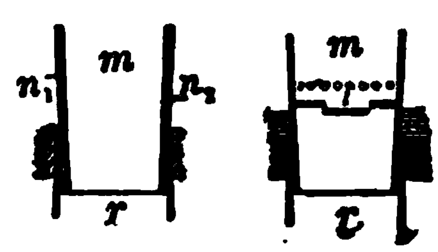

FIG. 13. FIG. 14.
GREINER'S Device for Ruissellement.

There are numerous other devices with the same object in view, which differ only in a very slight degree from the GREINER mode. For example, NATHAN-LEVY[2] (Fig. 15) places over the tubes, A, another tube, B, which is cylindroconical in shape. The smaller portion, E, is at a very slight distance from A, three projecting portions, T, keeping the

[1] J. d. f. d. s., 1, 3, 1860.
[2] Bull. Ass., 11, 522, 1894.

spacing constant. A portion, *C*, is soldered upon *B*, this cone resting upon the tube plate *P*, and consequently regulating the penetration of *B* into *A*. This cone, *C*, has a series of holes which allows the liquid to be evaporated to pass on to *E*, and the interior sides of the tubes, *A*, along which the ruissellement is effected. One of the advantages pointed out in favor of this arrangement is that the tubes may be readily taken apart.

FIG. 15.—NATHAN-LEVY's Contrivance for Ruissellement.

Experience has apparently shown that the objectionable feature of the NATHAN-LEVY device is that the annular space between the tube proper and the upper cylindroconical tube becomes clogged. By the SCHWAGER (Fig. 16) arrangement this difficulty is obviated by simply allowing the liquid to flow over the upper side of the adjusted tube at *d*. It is very important to have the levels of these juice distributors perfectly horizontal and to keep the saccharine liquid exactly at the necessary level, which makes them consequently of very little practical value.

According to BATTUT,[1] CLAASSEN was the first to propose a reduction of the diameter of the tubes of the multiple effects in order to obtain a thin layer of the liquid with a view to increasing the evaporating power of the apparatus. This idea of tube reduction was effected by CANARD,[2] by introducing sticks of wood into the tubes (Fig. 17). If the interior diameter of the tubes is 45 mm., and a stick 37 mm. in diameter is introduced, there remains an annular space of 8 mm. which is kept constant by suitable pins, *B*.

FIG. 16.—SCHWAGER's Tube.

MONTAUBAN[3] and MARCHANDIER proposed that instead of wooden sticks bars of iron with exterior enamel might be used. The sticks are attached in such a way that they do not touch the sides of the tubes, and are fastened so that they have an up-and-down motion. Under these circumstances there is a ring of juice, which is forced to circulate along the sides of the tubes in thin layers, and the

[1] J. d. f. d. s., 36, N. 22, 1895.
[2] Bull. Synd., 16, 326, 1894.
[3] La. S. B., 23, 391, 1895.

resulting vapors or steam formed combines very thoroughly with the juice with which it is brought in contact. It is claimed that the heating under these circumstances is more rapid than if the tubes were full of juice or old methods were used. It must not be forgotten that if by one means or another it is possible to increase the efficiency of an evaporating appliance, an additional and corresponding quantity of steam will be needed for the heating.

A special beet-juice evaporator[1] (Fig. 18), which has been attracting some attention, is arranged so as to allow the juice to enter from the bottom of each compartment into a special chamber, *A*,

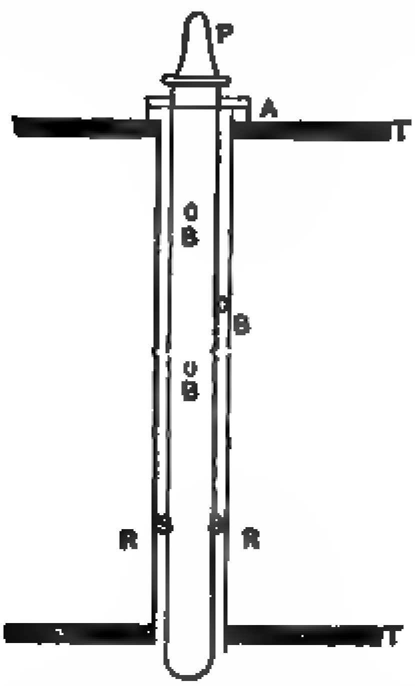

FIG. 17.—CANARD'S Stick for Ruissellement.

FIG. 18.—PORTEMONT Arrangement for Ruissellement.

and pass from there into the intertubular space, consisting of concentric tubes, the smaller of which, *E*, has interior steam heating, while the larger is heated externally. The evaporation is very active and should be regulated so that the overflow on the upper plate, *B'*, shall immediately run off through special pipes into a receptacle, *G*, from which it is drawn through *N* into the second compartment of the evaporator. This is to prevent the juice from running down the sides of the pipes being heated and thus mixing with the liquid not yet evaporated. The gases which may form in the inner pipes may be drawn off by a special pumping attachment.

BOUVIER (Fig. 19) realizes evaporation in thin layers in the following manner: The level of the juice does not reach the lower extremities of the tubes. A long hollow stopper, *a*, is inserted in

[1] Z., 49, 88 f., 1899.

the top of the tube, allowing the resulting vapor to escape through the centre, while the juice introduced above the upper tube plate will flow in a thin stream between the stopper and the interior of the tube, under which conditions the evaporation is very active. By a special arrangement the juice is continually renewed on the upper tube plate. It is interesting to note that the stopper has a prolongation of 10 cm. from its lower conical portion, the object being to collect a certain volume of liquid beneath the tube plate. It is claimed that a double evaporation between the two portions of the liquid results.

FIG. 19.—BOUVIER'S Stopper.

In the DOLIGNON (Fig. 20) device the juice from the compartment of the multiple effect penetrates the tube, *D*, at the bottom, while at its top is a distributor, *B*. The froth created during boiling will fall through the central tube, *A*, toward the bottom of the apparatus. The position of the tube, *A*, at the centre of *D* is assured

FIG. 20.—DOLIGNON'S Ruissellement Tube.

FIG. 21.—LACHAUX'S Tube.

by the distributor, *B*, and the ring, *C*. The LACHAUX (Fig. 21) tube has an important feature. In the interior of *A* is another tube *B* in the shape of an *s*, and soldered to the inner side of *A* at its extremities, *O* and *O′*, so that steam may readily circulate in its interior. It is claimed that by this arrangement the heating surface of the apparatus is considerably increased. Again the main

idea is the reduction of the diameter of the tube proper with the same object in view as in the previous cases.

Objectionable features of the ruissellement.—The question arises, how are these tubes to be cleaned? The different modes under consideration have one very objectionable feature which is, that the liquid is frequently projected with force, and there follows considerable entrainment from the apparatus. To overcome this difficulty RASSMUS arranges above the tubes a sort of hood which breaks the momentum of the liquid. According to BATTUT[1] the wooden sticks placed in the tubes tend to increase the efficiency of the apparatus and diminish the incrustations by one-half. He states that one of the objectionable features of this mode is that the juices have a peculiar color after circulating in tubes recently cleaned by ordinary methods. During the washing of the apparatus the wood absorbs hydrochloric acid, which is never thoroughly neutralized during the subsequent washing with soda, and partially inverts the sugar.

In theory all methods based upon ruissellement increase the efficiency of an evaporating apparatus without increasing the heating surfaces, and, furthermore, diminish in an important measure the space occupied by the juice. From the same point of view every effort should be made to reduce to a minimum the dead space between the lower tube plate and the bottom of the compartment of a vertical multiple effect. PORKONY points out that according to his experiments there is a great deal of dead space in a vertical multiple effect. In one case the juices remained in a triple effect three hours and twenty-three minutes until it reached the desired concentration, and during this time there must be considerable inversion by heat.

In some appliances the liquid to be evaporated must be constantly renewed by the assistance of a pump. If, with the intention of avoiding to a certain extent this pumping, the thickness of the layer of liquid to be evaporated is reduced, and the holes of distributing pipes are made smaller, serious obstructions necessarily result. If, on the other hand, the distributing orifices are made large enough to overcome the difficulty, the evaporating capacity of each element would be so large that pumps of great size would be needed. DESSIN declares that the best results are obtained by adopting a half-way method, and recommends the use of a type of circulating

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[1] J. d. f. d. s., **36**, No. 22, 1895.

pump having a capacity two or three times the volume of the initial juice entering the multiple effect. Many of the ruissellement evaporating apparatus, built according to purely theoretical data, have been irregular in their working, which explains why they have not been more generally adopted.

Evaporation with decreased height of the juice.—CLAASSEN[1] says that instead of resorting to ruissellement it is better to reduce the height of the juice in the tubular cluster. The thickness of the liquid mass is reduced by two-thirds and, even with a relatively small fall of temperature, the apparent level caused by the bubbling of the mass will rise to the upper tube plate, moistening all the heating surface, which is thus entirely utilized. This mode of conducting the evaporation results in a better utilization and a greater total fall of temperature, with an increase in the partial fall in each compartment, which in many cases may be sufficient to give to the apparatus the increased efficiency needed. The comparatively small expense of this arrangement, compared with ruissellement, resulted in preference being given to it. There is no difficulty in cleaning, while the cleaning of ruissellement devices is tedious and difficult. The only danger connected with the decreased-height method is the partial drying, which occurs in some portions of the compartment, where, for one reason or another, the boiling ceases, and the boiling spray does not reach the upper tubular plate. The consequence of this is a certain coloration of the juices.

The lowest possible level of the juice, as shown in the level gauges, in accordance with the law of equilibrium of fluids, depends upon many circumstances, the most important of which are the viscosity of the liquid and the volume of vapor liberated by a given quantity of water. One may keep the level of the juice lower in the concentrated-juice compartment of the apparatus than in the first compartment containing diluted juices. The most desirable level will be shown by experience. One need only arrange so that the frothy juice continuously flows over the sides of all the tubes.

For example, suppose that in the first compartment the efficiency is the greatest when the juice is at a level of 200 to 300 mm. in the tubes. It was previously pointed out that the long tubes in a vertical evaporator were objectionable; evidently when the evaporation is conducted at a low level the objections no longer hold

[1] Z., 42, 554, 1892.

good. In most cases the shortening of the heating tubes is not only unnecessary, but has an objectionable influence upon the efficiency when the juice is at a low level in the evaporator, as the bubbles which are constantly being formed and running over the borders of the tubes are then thrown into the air, resulting in a frothy juice. As a consequence the tubes are covered over their entire length with moving juice which is constantly renewed, but owing to its frothy nature only a very moderate pressure is exerted upon the bubbles formed. The greater the length of the tubes, within reasonable limits, the greater will be the velocity of the juice in their interior, without any appreciable increase of pressure in the lower part, and the greater will be the efficiency of the heating surface.

It is claimed that the conditions of pressure of the liquids upon the lower part of the heating surface is not influenced by the ruissellement, as the water level shows that the level of the juice is low, and, therefore, that there is a very light bottom pressure. There is frequently a bubbling over to a height of at least one meter above the upper tube plate.

Working by the two-third full method permits one to obtain a fall of 15° C. in temperature in each compartment instead of 12° C., as previously shown to be the case when working by the now obsolete mode. This means an increased efficiency of 25 per cent. If only one-third full the fall will be 17° C., which would correspond to an increased efficiency of 40 per cent. Experiments show that the coefficient of transmission in a triple effect is 2.50 in the middle. CLAASSEN'S experiments with reduced height and ruissellement show that the practical coefficients are as follows:

Ordinary working	2.50
Two-thirds of tubes covered	3.00
One-third of tubes covered	3.36
Ruissellement	2.90

The appliances mentioned in the foregoing are not suitable to the ruissellement for horizontal multiple effects, in which the evaporation is always conducted at low levels. In horizontal evaporating appliances the juice should be kept at as low a level as possible, but even then the same satisfactory result as is realized in the vertical types of multiple effects is not obtained. On the other hand, it is possible, in a horizontal construction, to have considerable heating surface with a low level of juice at the bot-

tom, provided the shape is that of a box. In such cases this system may be preferred to all others.

Yaryan and Lillie evaporators.—These multiple effects are important and interesting departures from those discussed in the foregoing, and deserve special mention. At the beginning the ruissellement was effected in the two cases in very much the same manner, though one is horizontal and the other vertical. Later the two were combined and there resulted new types. The YARYAN (Fig. 22) evaporator, as introduced into an European beet-sugar factory, consisted of a long cylinder, *H''*, containing a horizontal tubular cluster, heated on the outside with steam introduced through the pipe, *K*. The evaporation is accomplished in the interior of the tubes which terminate in the cham-

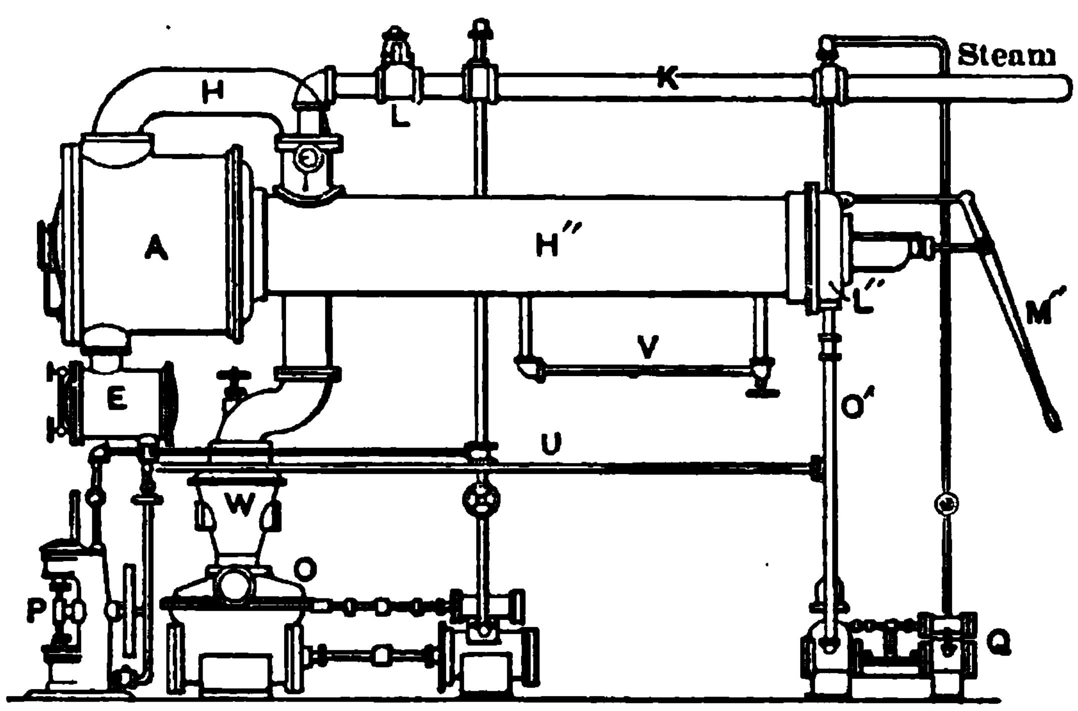

FIG. 22.—Side View of YARYAN Evaporator.

bers *A* and *L''*. The juice to be concentrated is introduced by *L''* and leaves at *A*. The pump, *Q*, forces the juice into *L''* (Fig. 23), the juice enters the tubes, *T*, through the openings, *e*, which are of smaller diameter than the tubes. In order to regulate the efficiency of the apparatus conical pointers, *I'*, acting as obstructors are forced into the openings, *e*. The pointers are all fastened to one rod, *L'*, and a lever *M'*. The juice upon entering the tubes, *T*, will undergo a partial evaporation and force out the steam bubbles formed, in consequence of which there will exist a series of liquid props which will necessarily moisten the inner sides of the tubes from one end to the other. Evaporation and concentration will follow. This motion is repeated in the other compartments of the multiple effect. When reaching *A'* of the first compartment there is a series of baffle plates *h* (Fig. 24) which separate the

vapor from the juice, the latter running into E with a float a and valve b, from which a pump takes it up to force it into another compartment of the apparatus which has very much the same

FIG. 23.—Detail of YARYAN Regulator.

construction. One of the principal advantages of the YARYAN apparatus is that the operation of evaporation is comparatively rapid, as the juice being concentrated remains in contact with the heating surfaces for a very short time, and concentrated juice is obtained almost immediately after the apparatus has been started. The fault found by JELINEK[1] with this evaporator is its cost. Other critics say that there is always considerable incrustation, while the reverse is claimed by numerous experts. Furthermore, one of its characteristic advantages is that it may be cleaned in twenty minutes.[2]

FIG. 24.—Detail of Condensed Water Collector and Steam Tramp.

The LILLIE evaporator represents one of the early modes of ruissellement (Fig. 25). The tubes are slightly inclined and open into a steam chamber S. The tube plate is 100 mm. in

[1] B. Z., 17, 185, 1892.

[2] Oe.-U. Z., 20, 17, 1891.

thickness, and the tubes are free at the other end. The attachment between the tube plate and the tubes is made without annealing. The evident advantage of this arrangement is that free expansion and contraction without obstruction are obtained. This condition does not exist when the tube plates are arranged

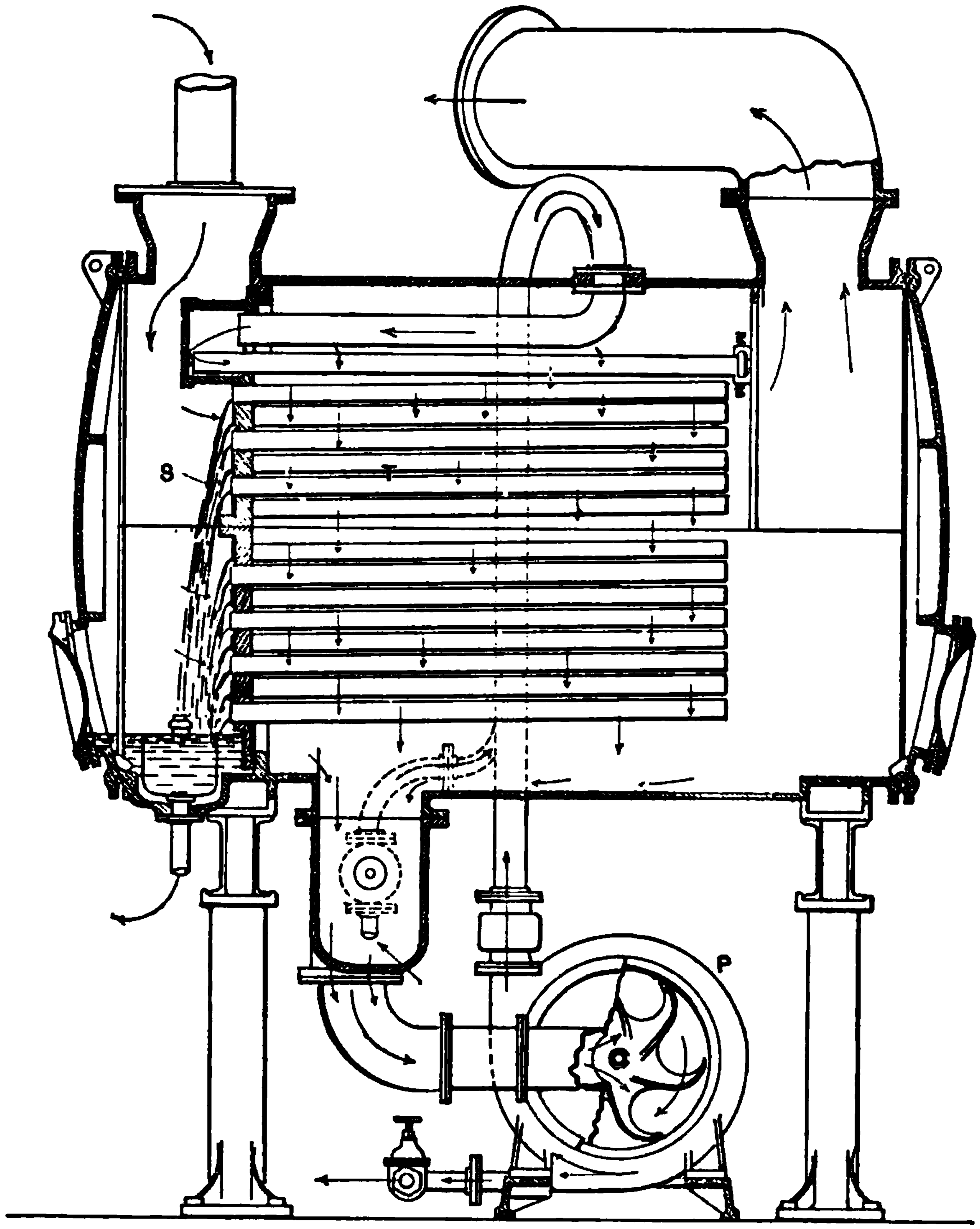

FIG. 25.—Section of LILLIE Evaporator.

as in most of the evaporating appliances, and the possibility of leakage is thus reduced to a considerable extent. The steam or vapor, as the case may be, enters *S* and from there passes into the slightly slanted evaporating tubes, *T*, producing the desired evaporating effect upon the juice on the outside coming from the circulating pump *P* and following the direction of the arrows.

The condensed water from the steam used for heating flows

back into the steam chamber *S*. The saccharine juice showers down upon the evaporating tubes during concentration. This juice, before entering the apparatus passes through a so-called balance valve regulated by a surface float. The combination is such that the supply meets the demand, in other words, the amount of fresh juice entering the evaporator is equal to the quantity evaporated. The circulating pump has sufficient power to send the concentrated liquor out into the air against the vacuum in the effect as well as to circulate the liquid, and consequently no tail or syrup pump is employed. It is pointed out that the vapor escapes freely from five sides of the evaporating tube. This is another important feature as compared with most of the existing multiple effects, for in the typical vertical kind the escape is only from the top. Another feature of the apparatus is the reverse mode of working. By the assistance of the circulating pump the liquor may be taken thin into the coolest effect and discharged concentrated from the hottest effect, the reverse of the usual way of working. It is claimed that the losses from entrainment are less than one one-hundredth of one per cent, and that the tubes do not need scraping.

The arrangement of the tubes in different parts of this evaporator are shown in Fig. 26. The drawing gives a very excellent idea of just how the juice enters the effect from the circulating pump, and its subsequent flow through the distributing tubes, which may be taken out from either end. The water of condensation flows into the steam chamber. Another interesting feature of the LILLIE evaporator is that the quantity of saccharine liquor that is being actually evaporated at a time is comparatively small as compared with the older methods, and this fact permits the duration of the process to be proportionately diminished. Under these conditions the dangers of inversion are lessened and, furthermore, there is less chance of coloration of the juice, which is an important factor.

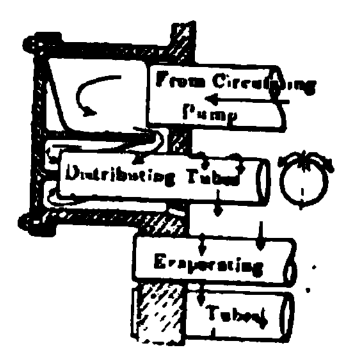

FIG. 26.—Detail of Evaporating and Distributing Tubes.

Theisen evaporator.—One of the interesting apparatus in which ruissellement is combined with evaporation in the open air is the THEISEN[1] evaporator, which consists of a cluster of tubes over which is placed a circular gutter into which flows the

[1] S. B., Feb., 1903.

juice to be evaporated. In this gutter a straining or filtering device may be placed which will retain or separate the mechanical impurities of the liquid before they enter the evaporator. The liquor flows in thin streams along the tubes, and at the same time and in the same direction air is drawn through by means of a suction device placed at the bottom of the evaporator. Under the tubes is a closed compartment from which the concentrated liquor can flow out through a syphon. The liquid that does not separate is held back by a special apparatus before air enters the exhauster. This appliance consists of a box in which are arranged a series of funnels with holes of varied sizes on top. The vapors are compelled to follow the sides of the funnels upon which the drops of liquid will collect. The interior of the tubular receptacle comes in contact with vapor or steam. The tension of the vapor evaporated is thus increased, and air becomes the more supersaturated with moisture.

A centrifugal evaporator of THEISEN'S[1] most recent design consists of a funnel heated on the outside and a rotating cone of a slightly smaller diameter with agitators. The juice enters at the bottom of the apparatus and rises along the surface of the revolving cone, and is projected against the funnel. The agitators, being nearer and nearer together when approaching the top, are sufficiently close to the funnel to force the juice, which the strong current of air in the apparatus would tend to send upward, in an opposite direction. The air in question is a considerable aid in the evaporation of the juice. At last the juice, considerably concentrated, collects in sufficient quantities in the funnel to have a natural flow through the bottom exit pipe of the evaporator. While the idea is interesting there is no indication of its practical application.

Circulation of steam.—In the vertical modes of evaporating juice the steam enters from the side—generally at the middle—into the calandria or tubular cluster. For reasons to be subsequently explained CLAASSEN points out that this is a mistake. The steam splashes the first tubes with which it comes in contact, and to prevent their destruction suitable obstruction plates which act as equal distributors are used.

During the past decade the methods of steam introduction have undergone numerous changes. Among these mention may

[1] Oe.-U. Z., **31**, 1024, 1902.

be made of the construction which had the object of dividing the current of steam into three parts, which passed separately through the tubular cluster divided into three sections. For various reasons the idea was of very little practical value. DESSIN recommends a vertical passage along the entire height of the tubular cluster and connected with the steam-distributing pipe. The admission of the steam into the calandria is assured by three or four openings of a total area slightly greater than that of the steam-distributing pipe. Under these circumstances the steam upon entering the tubular cluster, which has to be heated on top and at the bottom, will have ample intertubular space along the entire length of the tubes.

The question of distribution of vapor through the tubular clusters has been the subject of numerous inventions and discussions. As a general thing such combinations have never given the expected results. The best arrangement is to have few or no baffle plates. Under all circumstances they should be closely connected with the extraction of the air, the incondensable gases and vapors, and with the evacuation of the condensed water.

Fig. 27 is a section of the tubular cluster. A central tube of larger diameter is intended to facilitate the downward movement of the cooled liquor to the portion where the heating is most active, and should consequently be placed in the coolest part of the apparatus; that is to say, at the termination of the steam circulation, which justifies the spiral baffle plates. At the extremity of the steam circulation should also be placed the ammoniacal extractors and the exit pipe for condensed water, shown in the drawing near the centre. Furthermore, the lower portions of the baffle plates should have a jagged surface so as to allow the vapor that condenses immediately upon entering the tubular drum to fall along the tubes to the bottom, and escape as rapidly as possible in the direction of the evacuation.

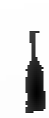

FIG. 27.—Detail of Tubular Cluster and Outer Drum.

In the FIVES LILLE apparatus a special passage is arranged around the calandria. The steam used for heating thus circu-

lates entirely around the tube cluster, entering through a series of holes which act as distributors. Fig. 28 shows a drum and tubular cluster without the large central tube, and in this case there are no baffle plates. In the vertical evaporators it is important that the maximum distance be travelled, for evidently the longer it is within reasonable limits the greater will be the velocity of the circulating steam or vapor. One of the objectionable features of this exceptionally long circulation is evidently the loss of energy due to various causes, and frequently the ultimate result is the loss on one hand of what has been gained on the other.

Fig. 28.—Drum and Tubular Cluster without Central Tube and Baffle Plates.

Removal of condensed water.—As already mentioned there is in the vertical multiple effects no difficulty in handling the condensed water, and in the horizontal effects the condensed water is, within reasonable limits, pushed through the tubes by the circulating steam into the chamber where the heating tubes terminate. Water must be removed from this chamber, otherwise the evaporating surface of the tubes would become inactive.

The condensed water cannot take a direction opposite to that of the steam from which it was obtained. On the one hand, this water would have to overcome the inertia of the vapor and, on the other, the friction of the steam with which it comes in contact and to which it is tied through an intermediary vesiculary strata would affect its circulation in the cooler parts of the apparatus, and thus, in an important measure, diminish the condensing power of the compartment. By having a rational exit the current of vapor, in its passage through the compartments, would tend to push forward rather than retard the condensed water.

It is to be noted that when steam is under pressure in the calandria there is no difficulty in removing the condensed water. The precautionary measure of preventing a loss of escaping steam is essential. Evidently when the pressure of steam used for heating is less than the atmospheric pressure, special arrangements should be adopted with the view to the removal of ammoniacal water. It stands to reason that the purity of the con-

densed water depends upon the purity of the steam employed, and it frequently happens that when the vapor used for heating is from another compartment of a multiple effect, in which ammoniacal gases are developed, the ammoniacal content of the water is very high. According to STAMMER[1] ammoniacal waters have the following composition:

COMPOSITION OF AMMONIACAL WATERS.

Constituents.	First Analysis.	Second Analysis.
	Per Cent.	Per Cent.
Organic substances.......	0.0014	0.0016
Inorganic substances......	0.0005	0.0002
Ammonia................	0.0059	0.0187

KASPAR'S[2] analysis showed that these waters contained 0.0136 per cent of ammonia and 0.0157 per cent of carbonic acid. It is pointed out that even if the ammonia combines to form a neutral carbonate there will remain 0.0016 per cent of free ammonia.

Evacuation of the condensed water from the compartments where the pressure of the vapor is higher than the atmospheric pressure may be accomplished with a floating purging device. The purger that has been in very general use for a term of years, and is still to be found in certain beet-sugar factories, consists of a closed compartment (Fig. 29) in which through the pipe, *a*, steam and condensed water are introduced. A receptacle, *b*, occupying the centre, slides on a central tube *c*. Water fills the exterior annular space and raises the float *b* which closes all communication with *c*. The water continues to enter, and when it finally runs over the sides of the receptacle its weight brings *b* back into its original position, forcing the water out through *c*. When it is half empty it will again close *c* until the overflow recommences, etc.

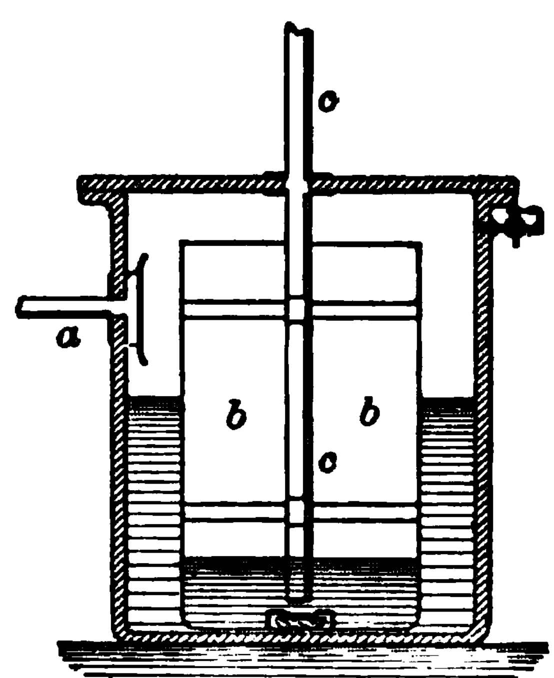

FIG. 29.—Steam Tramp.

Many other systems have been used for the same purpose. For example, the SCHAEFFER and BUDENBERG (Figs. 30 and 31)

[1] Z., 15, 288, 1865. [2] Oe.-U. Z., 17, 631, 1888.

appliance consists of a bent brass tube, *B*, the length of which is kept the same by means of a long iron rod *R*. When steam circulates in this pipe it will expand, and, as its lateral expansion

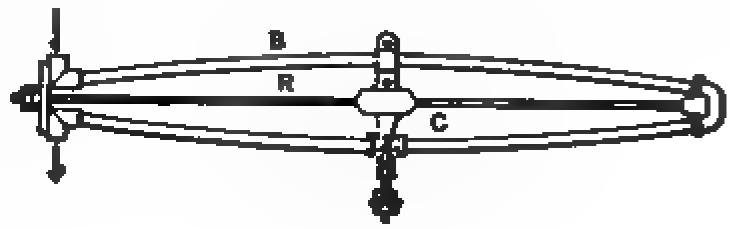

Fig. 30.

Fig. 31.
Schaeffer and Budenberg Steam Trap.

is prevented, it will bend downward where the tube offers the least resistance, and will thus close the passage for the steam circulation in the lower tube *C* by means of the valve *V* (Fig. 31). When the pipe becomes full of water the expansion is lessened and the valve remains open until the pipe is again full of steam. This purger may be readily kept under observation.

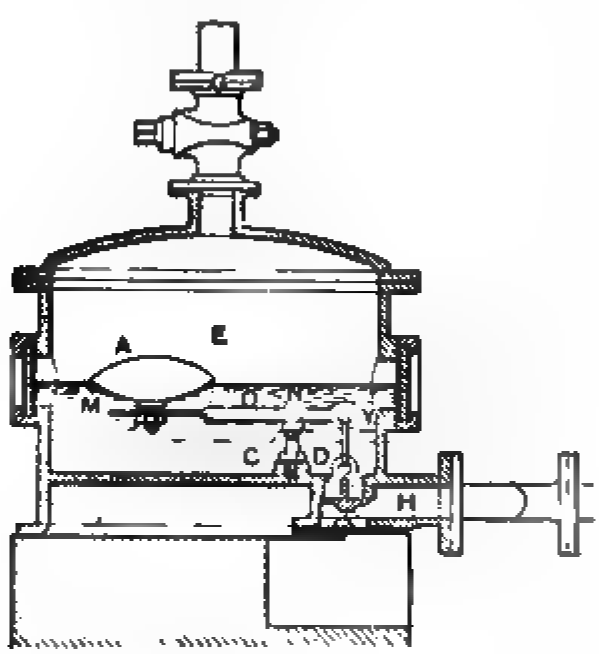

Fig. 32.—Daix Purger.

The Daix (Fig. 32) purger consists of a cylindrical receptacle, *E*, into which the water of condensation is introduced. When it reaches a certain level the float, *A*, is raised, and acting on a lever, *O*, opens the valve, *D*, which allows water to run off through *H* until the level in *E* is so much lessened as to close *D*. The upper pipe, *G*, is intended for the exit of the gases which would otherwise accumulate in the purger. Peep glasses are placed upon the sides

and permit one to follow the working of the apparatus. Numerous modifications have been made in this purger, especially as regards the valve which in most existing appliances is a balanced valve. Instead of the peep glasses exterior level tubes are used, which have the advantage of permitting one to obtain samples of the condensed water. If the valve was leaky it would evidently cause a considerable loss of steam, and if it should stick to its seat for any reason the water would accumulate in the calandria, hence it is desirable to have water levels in communication with that portion which would show whether water is accumulating there. Without doubt these purgers should be frequently examined during the sugar campaign. In certain special cases MALANDER says it is urgent to have upon the purger safety valves of exceptional size which communicate with the exterior and allow the steam to escape after it reaches an abnormal pressure. It is justly recommended that the cock above the purger be opened every now and then to prevent non-condensed gas from accumulating.

The return of the condensed water from the first compartment should be accomplished with a U tube having arms three to five meters high, arranged so that its free open orifice is somewhat lower than the bottom of the tubular drum. This arrangement assures in the compartment the desired pressure and the maximum temperature of the steam or vapor used for heating during the last period of its circulation; it also prevents the return of the condensed water into the compartment while the apparatus is not working. To increase or to decrease the efficiency of the apparatus, it is proposed to place at different heights on the pipe under consideration exit valves for the condensed water, so that the resistance of the water column, and consequently the pressure under which the apparatus is working, could be kept under thorough control.

VIVIEN and DUJARDIN[1] have proposed a mode to utilize the caloric of hot condensed water for the evaporation by circulating it from the heating chamber of one of the compartments into the following compartment, where, at the lower pressure prevailing, the water will give up its surplus of latent heat in the form of vapor. All the water finally reaches the heating chambers of the compartment of the concentrated juice, from which it runs off at a lower temperature. In order to render this idea practicable care should be taken that the exit pipe of the last apparatus is of considerable

[1] BREVET FRANÇAIS, 44, 2, 1883.

diameter, so as to obviate any possible accumulation of water in its interior. It is not quite clear what advantages of this plan are, as the caloric thus utilized in the multiple effect is lost for the boilers. Certain complications would necessarily follow if the arrangement was adopted, as it is difficult to regulate the passage of water from one compartment to another without carrying at the same time by entrainment a certain quantity of steam, unless well-arranged purgers are used.

In order to remove the condensed water from the calandria in the compartments where the pressure is less than the atmospheric pressure a pump is necessary; but it frequently happens that after the removal of the water the vacuum will rise in the pump itself or in the suction pipe, under which circumstances the water would at once commence to boil. In practice it is customary to place the pump at a sufficiently low level, so that the water accumulating in the pipes will compensate by its weight for the vacuum prevailing in the calandria, and under these conditions the pumping offers no difficulty. The best method consists in passing a long pipe from the calandria into a tank at a sufficient depth to compensate for the difference of atmospheric pressure, under which conditions all the condensed water will flow off naturally by gravity. The height between the level of the tank under condensators and the calandria of the last compartment of the multiple effect should be over six meters.

Generally there is a special pump for each compartment of the multiple effect. However, in certain cases only one pump is needed for two compartments, but as these connect in centres where the vacuos are different, the pump should be double in its action with separate suctions and a single force pipe. Certain precautionary measures must be taken to keep the packing of the pistons of the pumps in a perfect condition, otherwise there is constant danger of leaks, the suction being thus much reduced, and becoming entirely inactive where water finds its way to both sides of the piston. The RILLIEUX condensed-water separator (Fig. 33) permits the removal of this water from two compartments working under different vacuos. The compartment in which the vacuum is the lowest sends its water into

FIG. 33.—RILLIEUX Condensed-water Separator.

the compartment, *d*, from which it is removed through the pipe *O* by the ammoniacal pump. On the other hand, from the compartment in which the vacuum is greater the ammoniacal water runs into *a*, and when at a sufficient level the float *b* is raised and thus opens the valve *c*. By this arrangement the ammoniacal pump may also draw off a certain part of the water from the compartment, *a*. Suitable peep holes permit one to ascertain from the exterior just how the appliance is working.

Ammoniacal pumps. — Whatever the arrangement of the ammoniacal pumps they should be so constructed that their dead spaces will be reduced to a minimum, this being one of the essential conditions for their regular working. In order to produce suction where there is a partial vacuo it is necessary that their movement create a vacuo behind the piston greater than the medium from which they are pumping. Experience shows that if the ammoniacal pumps work too rapidly they don't work satisfactorily. The same thing is true of all pumps handling hot juices or water.

The ammoniacal water carries forward during the suction a portion of the incondensable gases, and these must be withdrawn from the pump. Furthermore, when the volume to be extracted is smaller than the pump's capacity there is drawn off in addition a certain amount of vapor and heavy non-condensed gases, such as carbonic acid, that accumulate on the bottom of the calandria. This within itself is a point in favor of the pump, but certain precautionary measures must necessarily be taken to prevent any loss of steam and any perturbation in the working of the pump. With this idea in view a reservoir is placed upon the pump, being connected with it at its lower portion, while at the upper portion is a pipe through which the gases are drawn toward the injecting condenser. A peep glass or a level indicator permits one to determine from the exterior how the pump is working.

As far as possible all condensed waters are used to feed the boiler, which necessarily brings about a caloric economy. The condensed water from the compartments of the multiple effect is also used for the same purpose; but this is objectionable if the water contains ammonia in excess or even small particles of sugar. The best practice is always to submit the water to repeated chemical examination. In certain factories it is customary to collect all the condensed water from the different compartments of a multiple effect into one receptacle and then pump it to where it may be utilized. Mixing the hot and cold water

is not to be recommended. The better plan consists in keeping separate the water that is at more than 100° C. and feeding the boilers with it, while the other water is utilized for the diffusion filter-press scum washing, lime slaking, etc.

Removal of non-condensed gases.—There is no way to prevent non-condensable gases from finding their way into the calandria. To meet the ammonia difficulty occurring during evaporation, and which always has a corroding influence on the brass tubes with which it comes in contact, PESSIER[1] proposes that the juice undergo a preliminary boiling with lime before entering the triple effect. It must not be forgotten that the lime is slow in its action upon amides, and this preparatory operation would demand considerable time. If this ideal condition of ammonia elimination could be realized it would not be possible to attempt concentration of juices in a multiple effect without having air in one form or another finding its way into the interior of the calandria. Consequently some special arrangement must be made to remove these gases. With this idea in view tubes are placed on the top of the vapor chamber communicating with the juice chamber of the apparatus, and the gases in passing from one compartment to another ultimately reach the condenser. In some cases these ammonia tubes connect directly with the condenser. CLAASSEN[2] has proposed to introduce steam or vapor at the bottom of the tubular clusters in the vertical evaporators so that they may push the non-condensed gases and especially the ammonia against the upper tube plate. This arrangement appears to have practical advantages.

The evacuation pipes should be attached only to the upper tube plates at different places depending upon the number of tubes and the position of the steam distributors. If there is only one passage for the steam to enter the evaporating appliance the most desirable places to draw off the gases are at points on the periphery of the calandria at the greatest possible distance from the entrance opening and in the vicinity of the tube of circulation. If the steam enters by two passages, one opposite the other, it is important to clean out the portions between these openings. If experience shows that corrosion still continues in other centres evacuation pipes should also be placed at those spots, for without doubt these corrosions are positive indications that there is

[1] S. I., 37, 813, 1891.

[2] Z., 45, 687, 1895.

a permanent accumulation of gas. When the evacuation tubes are placed in position on the disk holding the tubes of the evaporator it is important not to allow the tubes in question to penetrate the steam chamber, but to shove them off on the lower level of the disk; otherwise instead of accomplishing the work intended they could help the gases to accumulate in spaces from which they could not be removed.

In the horizontal evaporators the steam always enters on the side, and the condensed gases are forced out with the condensed water to the end of the tubes where the tubular clusters are united. For this reason the evacuation pipes should be placed at the upper part of the evacuation chamber. If the pipes are not perfectly horizontal, but are slightly curved, the gases collect in them and they are soon eaten away.

As already explained it is not possible to remove the gases alone, relatively large quantities of steam being drawn off with them. CLAASSEN[1] estimates that the quantity of steam thus carried forward is 30 or 40 times more than the volume of the non-condensed gases. To regulate the ammoniacal gases drawn off small cocks or valves are used, but as may be imagined the fault found with these is that they are soon attacked by the ammonia and become leaky.

The volume to be removed must be decided by experience; too much does less harm than too little, as a small loss of heat is not as objectionable, as are the corrosion of the tubes and a decreased efficiency of the apparatus. Particular attention should be given to the regulation of this removal of gases from the evaporating-vapor chamber of the fresh juices, for the vapors from that compartment have a relatively high pressure and should be used several times in the following compartments. On the other hand, in the compartment which contains the concentrated juice the steam or vapor has been used several times and is under less pressure.

The valves should have a diameter so that the gases might be drawn off without the least fear, even when the valves are entirely open. One may give as a general rule for practical working that the valves or the evaporation cocks of the first compartment should have a diameter of only 5 to 10 mm., unless when larger valves are used they are partly closed, or the pipes have

[1] Ż., 45, 688, 1895.

blind flanges with holes of this size. The valves of the last compartments have a diameter of 25 to 50 mm., and should be at least half-way open. In order to keep the heat losses within reasonable limits the vapors drawn off, containing hardly 1 per cent of non-condensed gas, are not sent directly to the condenser, but go from the heating chamber to that part of the compartment where the juice is boiling. Under these circumstances this vapor is utilized in the following compartment of the series. Care should be taken to get rid of all the air in the apparatus rapidly and carefully, when the evaporator is first started and the heating compartments are entirely filled with air. The ammoniacal cocks are very useful in regulating the vacuum of each of the compartments of the effect; it is pointed out that the evaporating men frequently open them at the wrong time and thus destroy the equilibrium of the apparatus.

Ammonia carried with water evaporated from beet juices may be estimated at one-half pound per ton of beets worked. As ammonia has many important usages in agriculture, SIXTA and HUDEC[1] proposed to collect it by means of alum sprayed into the ammoniacal vapors, whereby a sulphate of ammonia is formed and the alumina precipitated. The appliance used consists of a tube three meters in length, near which are two reservoirs containing the liquid. Inside the pipe are several partitions, the purpose of which is to bring the alum for a longer time in contact with the ammoniacal vapors. The alum solution consists of one part alum to eight parts water. Efforts have also been made to collect the ammonia in a special absorbing apparatus, by using sulphurous or sulphuric acid and other agents as absorbents, in the hope that the cost would be covered by the commercial value of the ammoniacal salts thus obtained. These installations, however, have not been successfully introduced. They cannot obviate the losses of vapor, for the reason that other gases remain in the steam which should also be removed.

Sugar separators or "catch-alls."—During the boiling in a multiple effect there is always a more or less abundant projection which may be carried by the vapor into the calandria of the following compartment. Considerable losses occur from this source, and do what one may they continue to exist. BRETON[2] points out that the average loss of sugar is 0.30 per cent of the total

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[1] B. Z., **19**, 429, 1895. [2] DÉCLUY, Ralentisseurs, **46**, 1900.

weight of beets sliced and, furthermore, that the losses increase with the concentration of the juice. It is to be noted, however, that the actual losses are very much less, and PELLET[1] states that they need not be more than 0.14 per cent of the total sugar entering the factory in the beets. On the other hand, BATTUT[2] admits that the loss through entraînement is 0.089 per cent of the sugar in the beet.

The entraînement may be of various kinds, among which may be mentioned the outcome of excessive boiling, especially when the effect is conducted with an abnormal level of juice above the tube plate. There may then be detached large bubbles, etc., which are carried into the air up to a certain height. If the shape of the effect is faulty the particles in suspension may be carried into the calandria of the following compartment. There is also danger of excessive frothing during evaporation, due to the effect being too full or to a faulty mode of running the vacuum pump, or the composition of the juice may be responsible for it. All efforts should be centred upon the prevention of the occurrence of these phenomena, as no mechanical device can entirely overcome the difficulty.

The bubbles bursting on the surface of the juice will necessarily project particles of liquid into the air, which are so small that they are hardly visible to the naked eye. The largest ones never[3] rise in the vapor column more than 0.5 to 0.7 m., while some of the smaller ones attain one meter, but they all fall upon the liquid again immediately, only the very small ones being carried forward unless special precautions are taken. They may be collected directly if the apparatus is high enough.

It has, however, been maintained that the juice is not carried forward in the form of small drops, but in the form of vesicles that enclose, in a thin pellicle, a space filled with vapor. Such bubbles would evidently be readily carried by the circulating vapors, owing to their comparatively small specific weight and their large volume. According to HORSIN-DÉON the vapors liberated from boiling saccharine solutions will be superheated, for the juice boils at a higher temperature than would water under like conditions. This superheated vapor tends to rise, the motion absorbs heat from the cooler environment in which it is placed, and a film of water will be formed around the superheated molecule. This theory explains

[1] Bull. Ass., 9, 317, 1891. [2] *Ibid.*, 10, 158, 1892. [3] C., 10, 501 1902.

why the entraînement is greater in the case of boiling syrups than with less concentrated juices. DÉCLUY[1] in discussing the subject says that there can be no possible reason why during the movement of superheated vapors their molecules should not yield up their superheat, and that the theory of condensation in contact with the ambient vapor is not justifiable. All the information at our disposal throws very little light on the question as to whether sugar is carried out as a vesicle or in drops, but there can be no doubt that the entraînement exists, and to collect the sugar carried forward various contrivances are used.

Elements that influence entrainment.—There are numerous factors upon which the entrainment during evaporation depends: (1) Construction of the apparatus; (2) the extent of the vacuum; (3) the intensity of the boiling; (4) the height of the juice; (5) the viscosity and the nature of the juice. In theory the first difficulty could be overcome by constructing the compartments of the effect of such a height that the drops projected from the boiling juice at considerable velocity and height will reach a point from which they will fall with sufficient force to overcome the rising and pushing tendency of the liberated vapor. As the most desirable height for a compartment of a multiple effect CLAASSEN recommends 3 to 5 meters. The horizontal effects are built in the same proportions. The diameter of the compartment also plays an important rôle. The entraînement is necessarily considerably influenced by the velocity of the steam, and its influence is consequently lessened with the increased diameter of the appliances. If the circulation of the vapors be minutely examined it will be found that it is in the centre of the veins that the velocity is the greatest and it is there that the entraînement reaches a maximum.

HAUSBRAND[2] points out that the volume of steam and also its velocity in any given section of a compartment of the effect increases in a certain proportion with an increase in the vacuum. The pressure upon any given drop and the possibility of its being carried off with the vapor increases with the square of this velocity. Consequently it may be concluded that there is every advantage in building the effect so that it will work properly with the maximum possible vacuo. Under such conditions the drops carried away during entrainment will be reduced to a minimum.

The intensity of the boiling also has an influence upon the

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[1] DÉCLUY, Ralentisseurs, 11, 1900. [2] HAUSBRAND, Evaporating, p. 134.

entrainment, for the reason that the distance travelled by the projected drops increases with the extent to which the juices are boiled. It must be also noticed that the volume and consequently the velocity of vapor liberated are greater. As regards the influence of the height of the juice in the effect it is to be noted that the bubbles of steam from the bottom of the compartment, formed at a comparatively high pressure, will burst open with a force directly proportional to the difference of pressure between the upper and the lower surface of the boiling juice. Furthermore, the greater the reduction in the size of the vapor chamber, the greater will be the chances for the vapor to carry off the bubbles by entrainment before they have a chance to fall by gravity. If we admit that sugar vesicles are formed in multiple effects, they should be produced from viscous liquids such as concentrated syrups; but these being heavier are less likely to be carried off by entrainment. In view of these different actions, which tend on the one hand to diminish and on the other hand to increase the losses with concentrated juices, the fact remains that with the latter the entrainment is greater.

According to CLAASSEN the rapidity of entrainment depends upon the amount of vapor formed in the juice, and, consequently, upon the rapidity and energy with which the steam bubbles break open on the surface; also upon increase of viscosity and the velocity with which the liberated vapors circulate. Very few drops of juice are carried forward by entrainment in the first compartment of the multiple effect, as the escaping vapor, which is under pressure or under a comparatively slight vacuo, does not occupy much volume, the juice being thin and fluid and the velocity of the moving vapor small.

On the other hand, in the last compartment, where the vapor assumes a volume about six times greater than under a pressure of one atmosphere, the viscous juice is more or less pulverized by the bursting of steam bubbles. If the drops of juice thus produced find their way into the piping when the velocity of the vapor is 100 meters and even more, they are carried forward into the condenser and lost in the condensed water. It is certain, however, that in the compartment of concentrated juice, having a sufficiently elevated free space, there is only a very small quantity of juice carried by entrainment. This may be readily proved by estimating the sugar percentage of the condensed water.

Theoretical considerations.—While the so-called catch-alls are sometimes placed on the inside of the compartments of the

multiple effects, this is an exception to the rule. The best arrangement is to place them on the large pipes connecting one compartpart with another and intended for the passage of vapors liberated from the boiling juices. As these vapors move at considerable velocity it would be impossible to "catch" and collect the drops carried forward by entraînement without obstructing the vapor circulation so as to retard it very considerably. The only way to decrease the velocity of the circulating vapor is to increase the diameter of the pipe. This enlarged section is so placed that the change in motion is sudden. Do what one may all the particles of vapor will not change their motion under the same conditions; for example, those in the centre of the vein will have a greater velocity than those on the side, for the reason that they encounter less friction.

The practical experiments of HORSIN-DÉON[1] bring to light some important facts relative to the motion of vapor in the catch-alls. He took for a typical "ralentisseur" the so-called Hodek, and showed that vapors upon entering its interior will expand to fill the increased space. It is mainly the exterior portions of the veins that expand, and if it is desired that the interior vein shall also have the greatest possible expansion during its run, the catch-all must be sufficiently long, the best proportion being twice its diameter. It is shown that the best results are also obtained when the proportion between the diameter of the pipe connecting with the compartment of the multiple effect and that of the catch-all is as 1:3.5. During the passage of the vapors[2] through the catch-all the central vein is necessarily conical in shape, and it is claimed that around this cone there is an annular space where a certain vacuum exists, the ultimate effect of which is to burst the vesicles.

Other experiments show that if the direction of the vapors' run is changed the central vein will more readily expand. But the distance travelled between the entrance and exit of the catch-all continues to be a very important factor. In the Hodeks[3] with baffle plate the shape of the veins is changed, but the vapor taken as a whole moves with about equal velocity. A well-known authority[4] points out that in the case of catch-alls with comparatively small diameters the precaution should be taken not to contract the vein suddenly, as the entrainment would thereby be

[1] Bull. Ass., 15, 60, 1897.
[2] *Ibid.*, 10, 109, 1892.
[3] DÉCLUY, Ralentisseurs, 22, 1900.
[4] S. I., 12, 29, 1877.

increased. From what has been said in the foregoing one may conclude that it is important to prevent, by suitable obstructions, the formation of the veins, as when the velocity of the vapor is reduced the sugar in suspension will soon deposit.

Some of the most improved models of catch-alls have perforated baffle plates, but in regard to these there is much to say. It is not alone sufficient to give these holes a total section determined in advance, for the reason that one opening through which a gas may circulate will necessarily cause very much less friction than will two openings of the same total area. According to DÉCLUY,[1] for equal sections and conditions, the friction is approximately proportional to the square root of the number of perforations. The influence exerted is consequently very considerable. It is also important to mention that the efficiency of a catch-all increases with an increase in the friction of the moving vapors. Without doubt the thickness of the perforated baffle plates used in the catch-alls has an important influence upon the friction, hence it should be kept within reasonable limits.

The efforts to prevent entrainment of the drops has not been limited to mechanical means, and other modes have given more or less satisfactory results. For example, RINGHOFER[2] proposes to bring the vapor and froth, etc., in contact with a highly heated surface that will transform it into steam. Again, VIVIEN proposes to place the catch-alls, not in the hottest part of the factory, but outside of the building above the roof. The vapors then partly condense and the vesicles fall to the bottom of the catch-all.

Description of catch-alls.—HORSIN-DÉON, CLAASSEN, and numerous other authorities justly declare that the best device consists simply in having the evaporating chamber of the compartment of a multiple effect sufficiently high above the juice level to prevent drops from being carried forward through entrainment. DÉCLUY admits the truth of this, but says that this precaution alone is not sufficient to overcome the sugar losses in question.

One interesting idea[3] is that of placing in the last compartment of a multiple effect a wire cloth with a sufficiently close mesh to prevent the passage of the vesicles. In one of the CAIL

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[1] DÉCLUY, Ralentisseurs, 18, 1900. [3] C., 6, 693, 1898.
[2] D. Z. I., 24, 240, 1899.

(Fig. 34) combinations a sufficient number of small tubes are placed at the upper part of the evaporating chamber, *B*, to allow the steam to pass from it. Suspended over these tubes are half spheres that throw the suspended drops back upon a plate, *F*.

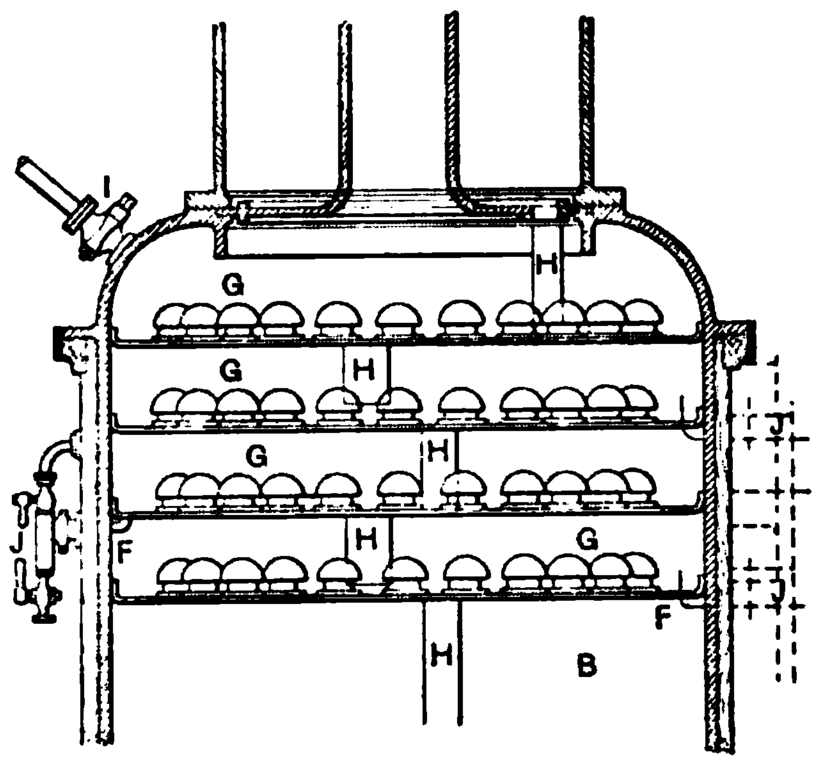

FIG. 34.—CAIL Catch-all.

Suitable pipes, *H*, permit the juice to fall from plate to plate back into *B*. There are many other combinations of the same kind, but few of them have continued in practical use.

Another type of catch-all, which is also called a Hodek after its inventor (Fig. 35), consists of a horizontal cylinder, *M*, of a diameter very much in excess of the pipe, *L*, through which cir-

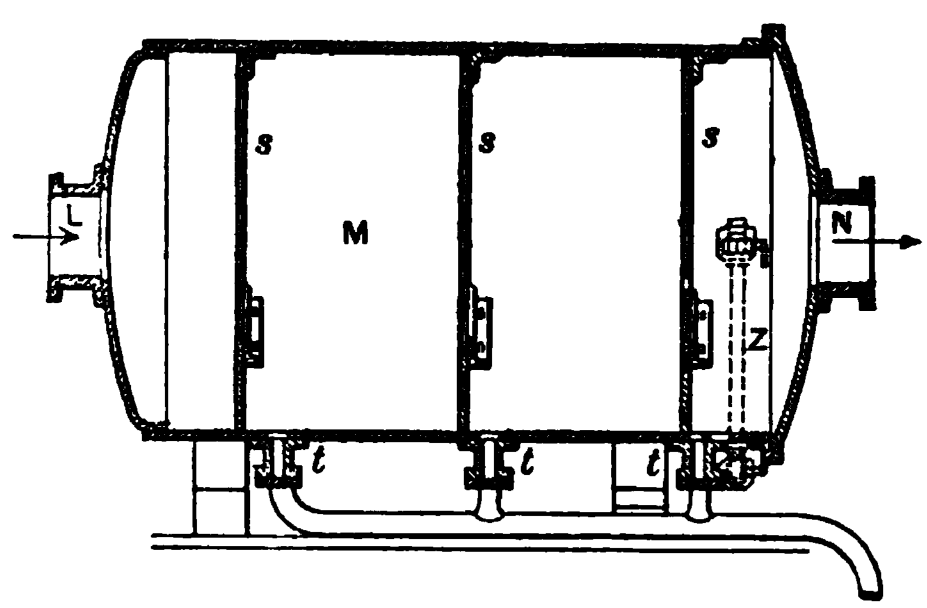

FIG. 35.—HODEK Catch-all.

culates the vapors liberated from the boiling juice. There necessarily follows a fall in the pressure and a reduction in the velocity of the moving vapors, causing a bursting of the vesicles. The perforated baffle plates, *s*, mechanically hold back the drops that are sufficiently heavy to be influenced by the obstruction, and they are then carried back by the pipes, *t*, into the compart-

ment from which they escaped. When the vapor has been freed of the sugar in suspension it passes out from the arrestor through the pipes, N, into the following compartment of the series. If the collecting pipes, t, become clogged, the water level, Z, indicates the existing conditions. In a more recent Hodek design there are seven perforated disks which act as obstructors, one placed at the entrance of the vapors, the other in the middle of the run, and five at the exit, the spacing between each being 15 cm. The efficiency of the apparatus depends upon its length.

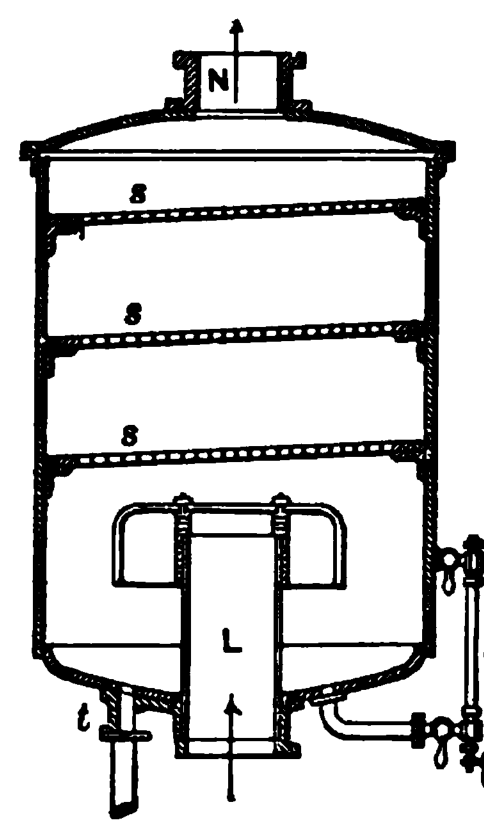

FIG. 36.—Vertical Catch-all.

The variations of this idea are almost without limit. Among them may be mentioned the vertical combination (Fig. 36), in which a hood placed over the entrance vapor pipe, L, acts as a sort of preliminary obstructor. Here, again, there are three partitions, s, which are slightly inclined, so that the drops all collect at one side. The condensed juice is carried off through the pipe, t. In this case also there is a level indicator. In the LENCAUCHEZ sugar arrestor there is a series of concentric filtering surfaces arranged so that the closed portions of one will be opposite the openings of the others, under which conditions it is claimed that all the veins will project the drops held in suspension against the baffle plates from which they run off.

It is seen that these safety chambers (Fig. 37) for multiple effects have many different shapes, but in reality they all work

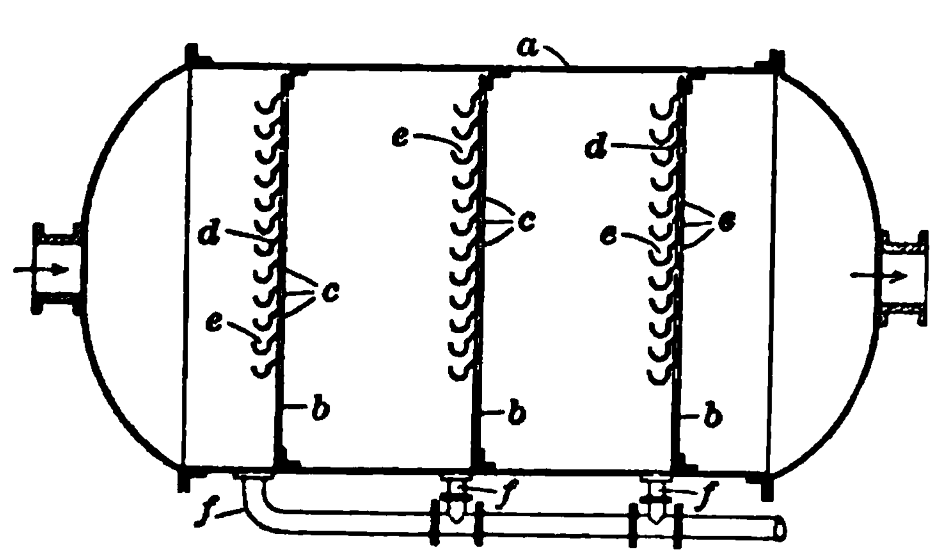

FIG. 37.—NEUMANN'S Sugar Arrestor.

on very much the same principle. The newest design has three divisions, b, in which are horizontal openings, c, through which

the steam passes; after having abandoned the particles of juice that have been mechanically carried forward these collect in special gutters, *e*, at a lower elevation and finally run off through *f*.[1] ABRAHAM[2] recommends that for all types of catch-alls, whatever their arrangement may be, a series of plates arranged very much like window blinds be placed in their interior. These plates form serious obstructors and the vapors are compelled to travel in and out of them, upon which they abandon the particles of juices carried forward by the vapors.

The ROEHRIG and KOENIG (Fig. 38) is an interesting apparatus which may be placed on top of the evaporating compartment.

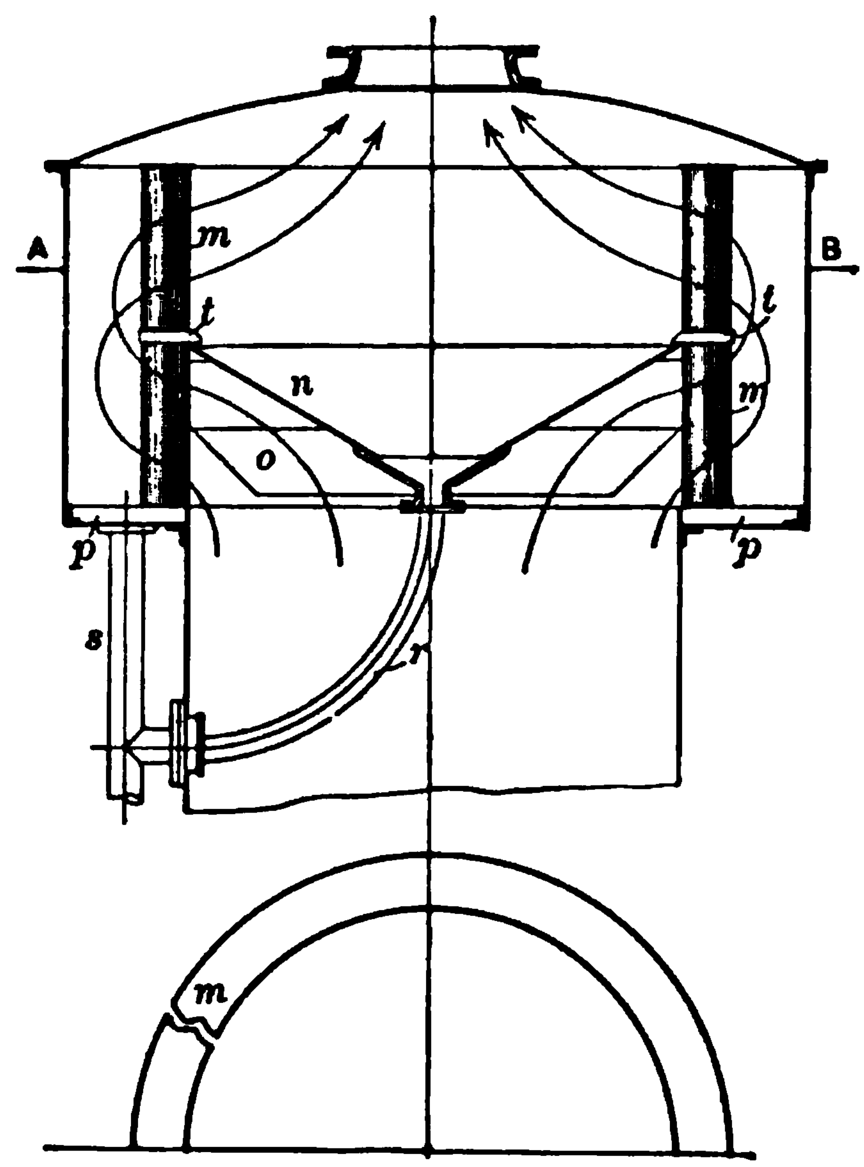

FIG. 38.—ROEHRIG and KOENIG Sugar Arrestor.

It consists of a compartment, *A*, *B*, very much wider than it is high, and greater in diameter than the pipe through which the vapors circulate upon leaving the effect. At a certain distance from the outside is placed a crown made up of pieces of thin undulated sheet iron, *m*, between which the vapor is obliged to circulate twice before escaping through the exit. The condensed juice thus separated flows back into the effect through *ps* and *nr*.

Of late years considerable attention has been given to a catch-all of enormous proportions of the DÉCLUY type. In this device

[1] D. Z. I., 25, 5te Beil., 1937, 1900. [2] C., 12, 1026, 1904.

there is no condensation of vapor and no return of juice to the evaporating apparatus. The appliance provides considerable surface of contact. At the CALLOO (Belgium) factory the sugar arrestor receives its vapors, first, from the fourth compartment of a quadruple effect; second and third, from the first and second vacuum pans respectively; fourth, from four vacuum crystallizers of 250 hl. capacity. It consists of a large cylinder 3.20 m. in diameter and 2 m. high, at the lower portion of which is a cone-shaped bottom, the point of the cone being connected with a pipe for the evacuation of the collected juice which is sent to a measuring receptacle. The upper end is also conical and terminates by a tube 60 cm. in diameter, through which circulate the vapors that have been freed of their sugar.

The vapors from the apparatus mentioned in the foregoing enter the sugar arrestor at the bottom. In its interior are placed the requisite obstructions which prevent the sugar in suspension from being carried forward. For this purpose a series of wooden laths are used, leaving 25 to 35 mm. spacing between two laths, that is, the spacing is the same as the total thickness of the laths. Upon these laths in a perpendicular direction is placed another layer; the third layer is so arranged as to have spacings in the reverse order to those of the first layer, while the fourth series leaves spaces which are reversed to the second layer, etc. Instead of wooden laths tubes, strips of iron, or other materials may be used. When the vapors come in contact with the first layers their motion is considerably retarded and the heavy particles fall to the bottom, while the lighter are carried forward. The first essential condition for a sugar arrestor is that the velocity of the vapor be retarded; this is accomplished by having a very large capacity for the receiver, to subdivide as much as possible the current of steam, and finally to offer to the finely divided vapor sufficient area to compel every particle to rub against its surface. During the 1899 campaign the quantity of sugar thus obtained was 0.15 per cent of the weight of the beets worked.

Upon general principles the construction of the sugar arrestors must vary with the manner of working the factory. By old methods the so-called Hodek gave satisfactory results, but at present, with the dry-air pumps as now used, combined with high pressure in the first compartment, their working is faulty, as the entrainment in such cases increases. Cases may be cited where, when the barometric condensers were first introduced, the entire condensed

water contained so much sugar that it had to be reworked in defecation and carbonatation tanks. At the CALLOO factory in 1897, with a vacuo of 68 to 70 cm. of mercury, the sugar of entrainment arrested was 0.186 per cent of the weight of beets worked, and in 1899, with 64 to 66 cm. of mercury vacuo, the amount of sugar arrested was 0.154 per cent of the weight of beets worked. In general it may be said that the entrainment is directly proportional to the vacuum.

Sugar-arrestors with reversed circulation.—There are several types of these arrestors. In the BRUNSWICK model the pipe for the entrance of the vapors from the effect is upon a different level from the exit, the vapors being thus obliged to travel in a zigzag direction and the drops and particles in suspension being thus eliminated or separated, owing to their being projected against the end plates. It is claimed that this arrangement does away with the resistance offered by the perforated plates in the typical Hodek (Fig. 39). In this case the condensed juice is drawn off at t as usual.

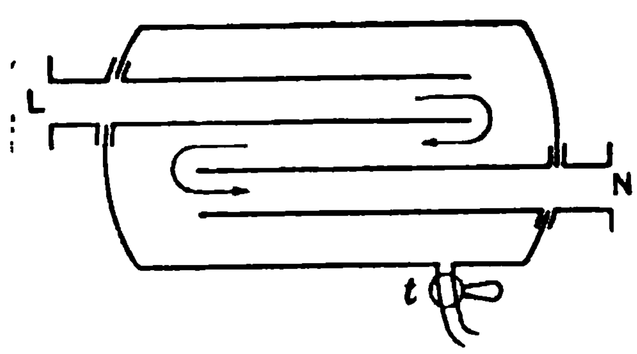

FIG. 39.—BRUNSWICK Catch-all.

SIMIRENKO (Fig. 40) has arranged a sugar arrestor upon an original basis that demands attention. It consists of a vertical receptacle which acts as a catch-all, in the interior of which is a partition, C, arranged so that it does not touch the bottom. The vapors enter at A and deposit their drops. The section of this compartment is thirty times greater than the pipe A. The vapors that are liberated of their particles in suspension leave at B, and the recuperated juice return by D to the effect.

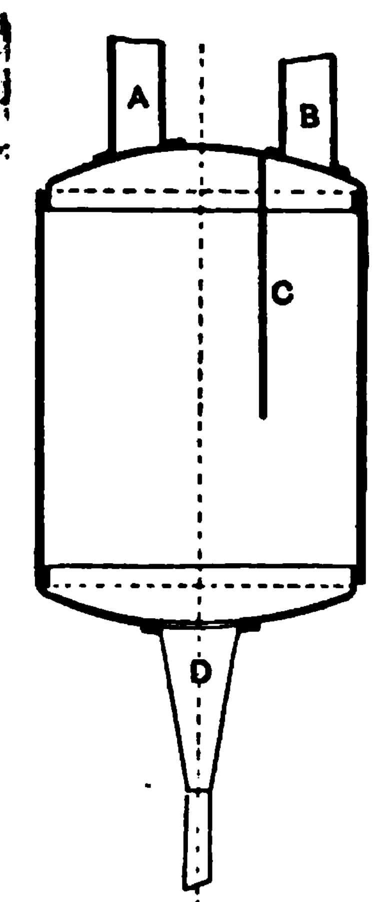

FIG. 40.—SIMIRENKO Sugar Arrestor.

The VON EHRENSTEIN[1] arrangement keeps back the vesicles of the vapors from the compartments of the multiple effect by introducing them in the direction of the tangent of the outer contour of a cylindrical receptacle. The vapors turn around the outer surface, and the motion ultimately causes the drops in suspension to collect

[1] C., 10, 385, 1902.

toward the centre; there they meet a metallic filtering surface against which they burst. The juice runs off from the bottom, and the vapor passes through the filtering medium and continues its run.

Among the new departures of sugar arrestors may be mentioned the PRILLWITZ mode, which consists of a wheel with projecting arms that drive the particles to be eliminated against the sides of the sugar arrestor. The motion is transmitted by a pulley or the steam itself.

The BOUILLANT (Fig. 41) centrifugal sugar separator consists of a turbine, placed in a compartment, in the direction of the axis of the flow of vapor, and having a velocity of 200 to 300 revolutions per minute. There follows a projection against the sides of the sugar arrestor and the resulting juice flows downward to escape through a special pipe.

By the HECKMANN[1] mode the vapors from the effect filter through a valve placed above the exit pipe. The drops are projected horizontally and collect around a pipe in a space forming an exterior reservoir. There is a slight expansion, followed by the bursting of the vesicles of the saccharine solutions.

FIG. 41.—BOUILLANT Centrifugal Separator.

The new desugarizor of the MUELLER design consists of a large funnel, over which is a ring that is placed in the evaporator, over the passage by which the vapors escape. The ring has lateral openings, so as to allow the vapor to penetrate in a direction tangent to its outer surface; then follows an enormous circulation. In the middle of the funnel, and directly above the pipe that returns the juice collected from the drops to the apparatus, there is a brush, the hairs of which hold vesicles that may be carried forward through the existing entraînement of the steam. Under these conditions they fall to the bottom into the juice being concentrated.

Almost all the combinations, besides those mentioned, which

[1] C., 10, 453, 1902.

consist of a sort of suspended compartment placed above the evaporating chamber, combining varied devices which form obstructions in the flow of the vapor, have to a certain extent been abandoned, as they do not give the results expected of them; the velocity of the vapor liberated in the effect being too great to be influenced by most of these means. The CAIL (Fig. 42) froth arrestor or destroyer consists of a cast-iron hollow column, *A*, with an

FIG. 42.—CAIL Froth Arrestor. FIG. 43.—VIVIEN Arrestor.

interior flue, *B*. Vapor enters by the tubes, *C*, passes into *B*, and escapes by *D*. The entrained liquid collects between the two concentric cylinders and returns to the effect. There is a level indicator, *E*. One of the characteristic departures among the sugar arrestors is the obtaining of the entrained sugar through the cooling of the vapors. The VIVIEN (Fig. 43) sugar arrestor consists of a vertical cylinder in which is placed a large pipe, *B*, through which the vapors circulate from one effect to the other. They enter on top at *A* and are in a measure cooled by passing over the cooler, *CD*, placed in the catch-all. There results a partial condensation. This necessarily means the removal from the vapor of the sugar

carried by entraînement. In order that the cooling need not cause a loss of caloric a juice, such as that from the diffusion battery, is circulated through the sugar arrestors of the different compartments.

Conclusion regarding catch-alls.—During many years past the writer has insisted that the catch-alls were not as necessary as is generally supposed, and without doubt when the evaporating chamber of an effect is sufficiently high and when the apparatus is properly built they may be done away with. The loss of sugar is more than compensated for by a decrease in the loss of the caloric of vapors passing through the arrestor. Whether the apparatus is used or not it is always desirable to make repeated analyses of the condensed water resulting from the vapors in question, using for this purpose the L naphtol which, according to MOLISCH,[1] permits the determination of 0.00001 per cent of sugar.

In the examples mentioned in the foregoing the arrested juice from the vapors returns to the evaporating chamber of the effect, but some experts claim that this practice is a mistake. RAGOT and SAILLARD[2] say that these juices always contain a certain amount of ferments which will have an ultimate reducing effect upon the sugars. RAGOT at his MEAUX factory combines them with the after-products before graining. The question remains, From what source do these ferments arise? Are they due to centres of infection in the catch-alls, the outcome of faulty cleaning? HORSIN-DÉON[3] suggested that the air from the arrestors should be removed just as from every tubular cluster, as otherwise the efficiency of the apparatus would be lessened, due to the existence of stagnant layers of uncondensed gases. With this idea in view suitable purger cocks are placed on all well-constructed catch-alls.

Compartment attachments.—When planning a beet-sugar factory it is always desirable to take into consideration the position of the evaporating appliance as regards light. The large glass-covered peep holes, or observation windows, permit one to note repeatedly the progress of the evaporation in the interior of the effect, and as they continue to a certain height of the compartment they permit observation even in case of excessive frothing.

With all the precautionary measures taken the observation made through peep holes is never entirely satisfactory by daylight. On the other hand, by placing a lamp in front of one window it is

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[1] Oe.-U. Z., 21, 379, 1892. [2] Circ. Synd., 767, suppl., 26, 1903.
[3] Bull. Ass., 16, 62, 1897.

visible through the opposite exterior window. It has been suggested to use interior electric lamps, but these must, in all cases, be thoroughly protected against the moist vapors. The CAIL (Fig. 44) arrangement possesses certain interesting advantages. The lamp, *L*, is introduced into the compartment of the effect through an opening, *PP*, and has an exterior glass cover, *V*, air being kept out of the evaporator by a suitable joint, *d*. The plate, *BB*, keeps the joint in position, and above this plate and screwed on by *g'* to its outer border is the plate which holds the electrical wires and the reflector *D* of the lamp. Multiple effects should have suitable steam pressure and vacuum gauges. Advantages are found

FIG. 44.—CAIL Lamp Protector.

in some cases in having mercury pressure indicators. These were first introduced into the beet-sugar industry by BRUMME.[1] The standard vacuum gauges whatever be their construction frequently get out of order. The vacuum gauges should be placed at an elevation above the juice level in the evaporating chamber, and a pressure gauge must also be placed on the calandria of the first apparatus. In the way of thermometers for multiple effects the mercury model is generally used, but is constantly breaking.

Level indicators render an important service, but very seldom work as they should by reason of faulty construction. The axis of the upper and lower sockets for the tubes should be in exact prolongation. MALANDER points out that such is seldom the case, and

[1] D. Z. I., 13, 1210, 1888.

the result is that air bubbles enter the tubes, preventing one from ascertaining the level of juice, and furthermore they break frequently. The tubes should be so arranged that about 500 mm. are above and 500 mm. below the normal juice level. Their diameter is generally about 25 mm.; if it be smaller the indications are not reliable. To the lower portion of the level indicators is branched a glass test tube, with which the indicator may be made to communicate. After closing all communications with the effect and opening a top air cock the liquid from its interior runs off. Level indicators should also connect with the calandria, so that the evaporating man may familiarize himself with the existing interior conditions of the heating chamber, in order to ascertain whether water has accumulated, which may be due to the stoppage of the ammoniacal water pump or to other causes. From a practical standpoint it is important that all the hand-working valves should be within easy reach of the evaporating man. Special pride generally exists in having the general exterior aspect of a multiple effect present the most attractive appearance; hence the wood lagging is repeatedly varnished and metallic portions polished every day.

CHAPTER III.

THE MULTIPLE EFFECT.

Historical.—No appliance or apparatus connected with the manufacture of cane or beet sugar has occasioned more never-ending discussions regarding priority of principle than the multiple effect. None of the data carefully examined are sufficiently convincing to decide the issue. PÉCLET maintains that the real credit should be given to PECQUEUR, while others insist upon the claims of RILLIEUX. According to PÉCLET[1] the principle of successive evaporations by means of the same heat appears to have been put in practical use in 1829 by PECQUEUR. Later other appliances were constructed upon the same basis, among which mention may be made of the RILLIEUX American appliance, the first application of which was in 1845. But the former apparatus was not combined to work in vacuo. HORSIN-DÉON[2] claims that RILLIEUX' first invention was brought to light in 1830, but that at that time the idea was not accepted. It is difficult to decide between these two opinions, as no official document recording the circumstance is known. On the other hand, it is said that RILLIEUX and PECQUEUR[3] worked together at about that period.

It is to be noted that the PECQUEUR appliance could not be adapted to sugar factories, as the heating surfaces of which he made use were exceptionally small, and, furthermore, the boiling was effected in some of the compartments at very high temperatures, while in the last section it was effected in the open air. The first document that the writer can find relating to this subject is the American patent No. 4879, December 10, 1846, when RILLIEUX gave his idea a practical application. It consisted of "a series of vacuum or partial vacuum pans so combined together

[1] PÉCLET, Traité IV, 2, 360, 1878.
[2] HORSIN-DÉON, Traité II, 1, 500, 1900.
[3] S. I., 16, 431, 1880.

as to make use of vapor from the evaporation of the juice in the first to heat the juice in the second, and the vapor from this to heat the juice in third, which latter is in connection with a condenser, the pressure in each successive one being less."

Principle of the multiple effect.—When a liquid is separated by a metallic partition from the vapor that heats it it will boil, provided the conditions of difference of temperature between the vapor or steam and that of the liquid are such as to effect a boiling. By creating a vacuum it is possible to increase this difference, as the liquid will then boil at a lower temperature than it otherwise would. When the boiling temperature is thus lowered it is evident that while keeping a difference of temperature amounting to a considerable number of degrees between the liquid that boils and the steam that heats a boiling with vapors at a comparatively low temperature may be effected, and the pressure may consequently be lower than the atmospheric pressure.

If in the second compartment of a double effect—that is to say, an apparatus in which the vapors from the first compartment are utilized for the heating of the second—a vacuum be made so that the absolute pressure will be only 0.15 of an atmosphere in the interior of the apparatus, the boiling point of the juice would from this condition alone be reduced to 55° C. In order to boil the juice in the first compartment of an evaporating appliance steam at more or less pressure is introduced into the calandria or tubular cluster, the liquid soon begins to boil, and the vapor from the juice finding its way into the tubular cluster of the next compartment will then condense and transmit its latent heat through the tubes to boil the exterior juice.

Boiling under the foregoing conditions can take place at 55° C. Certain phenomena then follow which were pointed out by Watt. When two receptacles at different temperatures contain the same saturated steam the tension of this steam corresponds to the lowest temperature of the two receptacles. In the case under consideration the liquid of the first compartment is heated to a certain temperature, and this is followed by a condensation of the vapors developed upon coming in contact with the more or less cooled surfaces of the calandria of the next compartment. In theory the tension of this steam should fall to that existing in the second compartment. But in the case under consideration the exchange of temperatures through the surfaces with which the steam comes in contact is not instantaneous, and in

order to effect a boiling of said liquid there must exist a certain difference in temperature between the heating steam and the juice to be concentrated. The temperature of the strata of vapor or steam which condenses upon the metallic surfaces will be slightly higher than the prevailing temperature of the second compartment. This would mean a vacuum in the second compartment greater than that in the first.

This idea may be followed throughout the entire working of a multiple effect in all its phases. If the double effect is changed into a triple effect the heating steam is introduced into the tubular cluster of the first compartment, from which the boiling liquid sends its vapors to the second. These condense at a temperature depending upon the temperature and the pressure of the second compartment, which also is under the influence of the third compartment. The argument for five, six, or any number of compartments holds good, but, unfortunately, after reaching a certain limit this simplified theory no longer agrees with the practice, as there is a limit under which the difference of temperature between the heating vapors and heated juice in each compartment is not allowed to fall.

Economy of the multiple effect.—While one calorie of heat raises the temperature of one kilo of water one degree, even when the water is heated up to its boiling boint, more heat is necessary in order to vaporize that amount. For example, to volatilize one kilo of water at 100° C., and under the average atmospheric pressure 537 additional calories are needed, its vaporized condition depending upon its power to hold the said caloric called latent heat of vaporization. Through condensation all the latent heat is necessarily liberated, and what remains is held in the water of condensation.

The vapor in passing from one compartment to the other is entirely condensed in each of the sections of the multiple effect, and the amount of heat thus liberated is transmitted without loss through the sides of the heating device into the boiling juice and is entirely utilized for evaporating purposes. All facts considered it is evident that by the combination under discussion this latent heat is in reality utilized several times for boiling the juice in the next compartment in which the pressure is kept lower, and herein lies the economy of this mode.

A kilo of steam, when condensing, will give very different amounts of heat, depending upon the temperature of the con-

densed water. Allowance should be made for the cooling which the condensed water undergoes when it flows along the heating tubes, and which may vary with the construction of the apparatus, but can never be very great. The higher the pressure of the vapor or steam used for heating the smaller will be the amount of the liberated heat through condensation, as the amount remaining in the warm condensed water increases. Consequently, it may be concluded that in a single-effect apparatus not one kilo of water, but always a fraction less, will be evaporated by one kilo of exhaust or live steam, and even in a multiple effect one kilo of steam does not evaporate two, three, four, or more kilos of the water contained in the juice, according to the number of compartments, but always less, depending upon the difference of temperature between the condensed water and the boiling juice. As these quantities of heat are not great they may be overlooked in many practical considerations.

Experience shows that it is impossible to attain so high an efficiency[1] on account of several other losses, as, for example, the loss by radiation, notwithstanding the employment of the most modern non-conductors, and owing also to the loss in head when passing from one compartment to another, losses of vapor through the ammoniacal gas pipes, and variations in the level and the density of the juice.

Schema of working of a triple effect.—The diagram herewith (Fig. 45) shows the circulation of the vapors of a triple effect, and if the series continues it remains unchanged, provided normal conditions of evaporation prevail. The steam is introduced into the tubular cluster of *I*, causing the boiling of the juice with which it comes in contact, and the resulting vapors escape through the large upper tube *T*, passing to the tubular cluster or calandria of *II*. Here the juice coming in contact with the tubes is again caused to boil, and these transformations continue from compartment to compartment. In the triple effect the vapors of the third compartment are sent to the condenser, in which the air pump creates the desired vacuum. The waters of condensation are removed from the tubular clusters through special bottom pipes, as explained under another caption.

As the juices upon reaching the first compartment undergo a partial concentration, the entrance and exit valves are so arranged

[1] Bull. Synd., 32, 723, 1900.

that all the juice from the filter presses enters into the multiple effect with the least possible loss of time. Furthermore, the juice in the compartments should retain its constant level, its temperature and the vacuum in the different compartments being regulated so as to allow the juice to be readily drawn from one compartment to the next one, the valves being regulated accordingly.

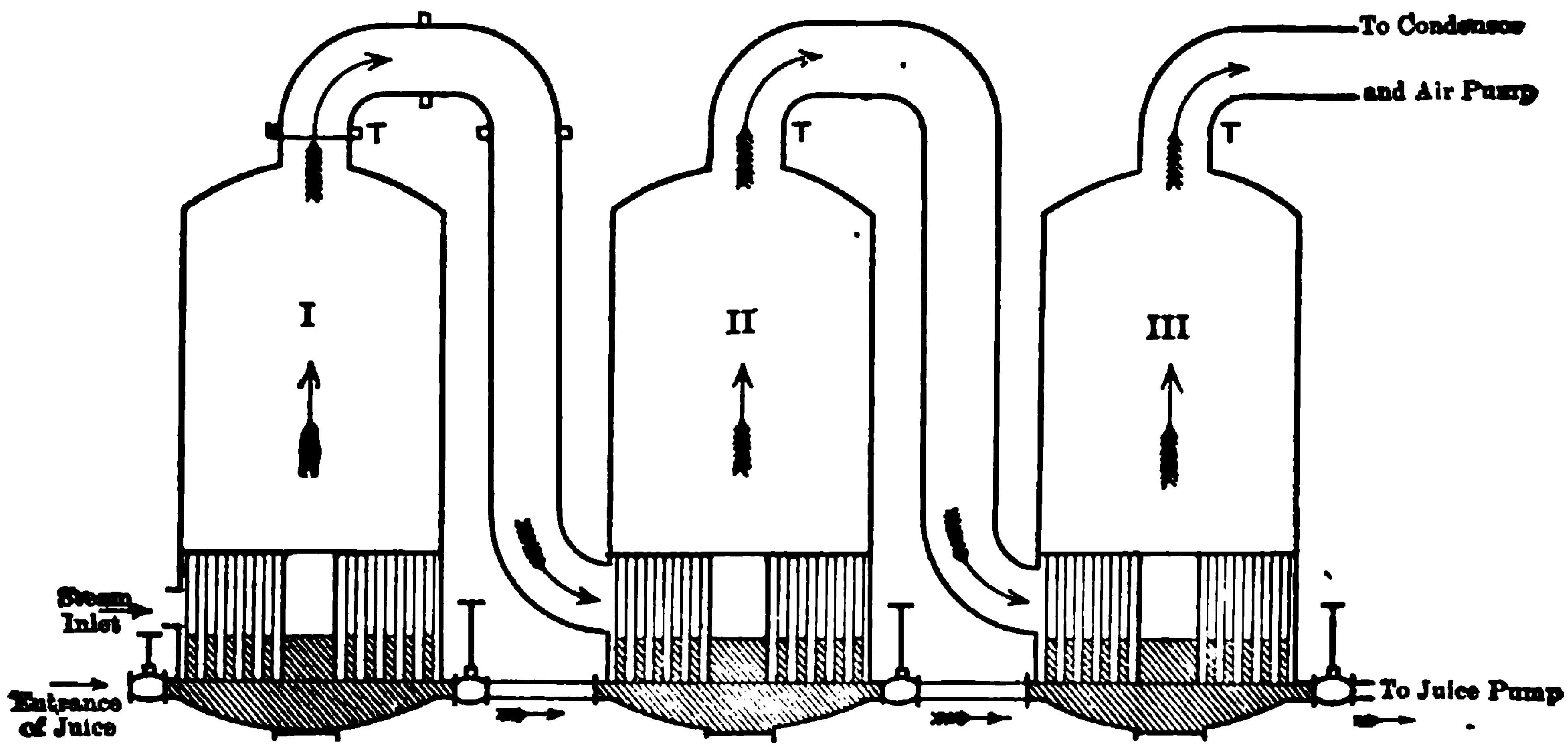

FIG. 45.—Schema of the Working of a Triple Effect.

Sizes of heating surface.—The installation of the evaporation apparatus should be such as to concentrate the juice to the desired density under all conditions that any emergency due to irregularity in the general working of the factory may create. Such irregularities, caused by the widely different kinds of work required of the evaporating appliances, can never be entirely obviated in practical work. They are due to certain features of the manufacturing process, such as the variable volume of vapor used during the different phases of graining in pan; furthermore, the juice obtained from the diffusion battery never has a very regular composition; sometimes the volume of juice removed is irregular, owing to interruptions of the working of the slicer, or to an irregular circulation in the battery; then, again, the carbonatation may be more or less rapid, or the flow of the filtrate from the filter presses may be irregular.

In other words, there is frequently an accumulation of juice, for which the waiting tanks would not have sufficient capacity if the evaporation in the multiple effect were not calculated upon

a basis allowing for an average volume of juice. It is desirable to allow for heating surface greater than that actually needed, as determined by calculation: first, for momentarily abnormal work, for which an increase of 10 per cent is about right; second, to obviate a reduction in the heat transmission which may be due to different causes.

Among the causes which influence the evaporation in the last compartment may be mentioned the viscosity of the concentrated juice, which condition obstructs the passage of the steam bubbles, the greater weight of the juice, owing to its concentrated condition, which influences the boiling temperature, in that it retards the transmission of heat through the tubular cluster, and the greater volume of vapor acting as a heating medium. Another fact not to be overlooked is the exceptional thickness of the deposits upon the tubes which necessarily causes a reduction in the transmission of the latent heat. These facts explain why, apparently, the last compartment should have a considerably larger heating surface than the others of the series.

On the other hand, there are factors which have an important contrary influence. The juice upon entering the first compartment must be heated to its boiling point, but when passing to the next compartment the amount of heat the liquid has stored up is greater than that which corresponds to the lower pressure that prevails in the following section; this excess of heat is liberated at the moment the juice enters in the latter and there follows a greater evaporation. All facts considered, less water need be evaporated in the last compartment of a triple effect than in the first and, therefore, in most cases the same heating surface is given to this compartment as is allowed for the first.

An idea that has for a long time been in vogue is that the size of the compartment should increase in direct ratio with the increasing prevailing vacuo. As the vacuum increases the volume of the vapor increases. The number of molecules directly in contact with the heating surfaces of the tubes evidently decrease in the same proportion, and such being the case the coefficient of transmission for a unit of fall of temperature decreases with the expansion of the steam. Consequently, if it is desired to obtain the same transmission of heat between the various compartments it necessarily follows that their respective heating surfaces must be proportionately increased. In 1881 [1] this ques-

[1] Oe.-U. Z., 18, 626, 1889.

tion was discussed in a special monograph, and it was pointed out that in order to maintain the same fall of temperature in the different compartments of a multiple effect, it is necessary to give them a heating surface proportionate to the volume of vapor that is constantly increasing from the first to the last compartment of the multiple effect.

According to JELINEK[1] the progressive increase in the heating surfaces of the compartments has no special advantages, for the reason that the coefficient of heat transmission becomes smaller and smaller, and the efficiency of the compartments per square meter necessarily decreases in the same proportion, which means that their hourly evaporating capacity becomes less as the evaporating progresses. The RILLIEUX calculations show that in a standard evaporating appliance the three compartments should have the same diameter, and HORSIN-DÉON held the same view. The most advanced theories, such as CLAASSEN'S,[2] recommend the reversal of the order of these dimensions. According to this authority[3] the coefficient of transmission of heat increases proportionally to the fall of temperature in the apparatus. The augmentation of the coefficient for 1° C. fall in temperature was hardly perceptible in the limits within which the experiments were made. This increase, however, becomes still smaller when the fall of temperature is greater. The coefficient of transmission of heat augments with the increase of the temperature of the steam used in heating and that of the liquid being boiled. For steam heating temperatures higher and lower than 100° appear to act very differently. From what has been said it is evidently desirable to increase the coefficient of transmission in the last compartment of the multiple effect.

The available methods for increasing the heat transmission in this section are to increase the fall of temperature and to maintain a boiling temperature that is not too low, *i. e.*, to maintain a moderate vacuum. If the vacuum is raised above 60 cm. of mercury the fall of temperature will increase considerably with each additional centimeter of vacuo; but it would appear that under these conditions the coefficient of heat transmission decreases more than that which can be gained by increasing the fall of temperature. Therefore, it is useless to push the vacuum much above 60 cm. As such a vacuo is difficult to reach, unless one uses large volumes of cold water

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[1] B. Z., 15, 98, 1890. [2] J. d. f. d. s., 35, 21, 1894. [3] Z., 52, 373, 1902.

and air pumps working in a very thorough manner, the general expert opinion appears to be that the limit mentioned is the best.

Another mode of increasing the efficiency of a multiple effect is attained by increasing the total fall of temperature of the system, but, as the final temperature cannot be lowered beyond the limit corresponding to a 60 cm. vacuum, it becomes necessary to increase the temperature of the vapor used for heating, the fall of temperature then becoming greater for each compartment. The division of the total fall should be so arranged that the lowest admissible fall of temperature occurs in the first compartments, the remainder of the fall occurring mainly in the last compartment, where the evaporation reduces the juice to a syrup. As a result the heating surface of the first compartments of the series should be increased as the fall of temperatur decreases, so that the desired volume of water may be evaporated from the juice, while the heating surface of the last compartment, for the concentrated juice, could be comparatively small.

The basis upon which the heating surface of a multiple effect is calculated depends upon the coefficient of heat transmission. The following data according to CLAASSEN may be considered as averages:

In a quadruple effect, in the first compartment and in the pre-evaporator, 40 to 50; in the second compartment, 30 to 40; in the third, 20 to 30; and in the fourth, 10 to 15. In a triple effect, in the first compartment, 40 to 50; in the second, 30 to 35; and in the third, 12 to 15. The essential condition for using these figures is that the multiple effect in question be properly combined and carefully handled.

Limit of the theoretical efficiency of a multiple effect.—In theory one kilo of steam will evaporate 3 kilos of water in a triple effect, 4 kilos in a quadruple effect, etc. Consequently, the efficiency apparently increases with the number of times the vapors are utilized. As a matter of fact there cannot be any gain in the efficiency of a multiple effect by introducing another compartment, but a saving in the quantity of steam used. For an equal heating surface the efficiency of an evaporating apparatus is inversely proportional to the number of compartments, consequently, there is a rational limit to the subdivision which must not be exceeded on account of the cost of the apparatus for a given efficiency. Furthermore, it is necessary that the temperature of the vapor of one compartment be high enough to boil the juice in the following compartment of the series, and that there prevail sufficient difference between the temperature of the heating vapor and that of the juice being boiled.

The steam used for heating in the first compartment is generally at 115° C., in the last compartment the syrup is at 55° C, thus leaving a margin of only 60° C. This total fall of temperature cannot be fractionated indefinitely; on the contrary, for each of the compartments there is a minimum limit for this fall under which it is no longer possible to obtain a rapid evaporation, even when the heating surface is increased. Experience shows that in the first compartment, where the juice is boiling at 100° or more, the fall in temperature cannot be below 5° to 7° C., in the middle compartment not less than 7° to 10°, and in the last compartment where the juice is reduced to a syrup not below 15° C.

It follows that the fall of temperature cannot be divided into a very great number of fractional parts. A sextuple effect may be considered as the extreme limit of the number of compartments in which it is desirable to work a multiple effect in sugar factories. The utilization of exhaust steam in an apparatus of this kind offers many difficulties, according to Claassen, and, even the quintuple effect is not altogether practicable, so that the triple or quadruple effects are the types generally used. In many cases the triple effect continues to be in vogue. A triple effect with 300 sq. m. of heating surface will have the same evaporating efficiency as a sextuple effect with 600 sq. m., so that by increasing the number of compartments the total area of heating surface exceeds all rational proportions. A simple calculation shows that the resulting steam economy does not compensate for the extra expense of these enormous evaporating appliances. Following tabulated calculations herewith make this fact very evident. A glance at this table shows that even after a quintuple effect the economy is excessively small.

Steam Economy Effected by Increasing the Number of Compartments.

Number of compartments used.	Juice evaporated by one kilo of steam.	Economy as Compared with Effect.						
		Single %	Double %	Triple %	Quadruple %	Quintuple %	Sextuple %	Septuple %
	Kilos.							
Single	1							
Double	2	50						
Triple	3	66	33					
Quadruple	4	75	50	25				
Quintuple	5	80	60	40	20			
Sextuple	6	84	66	50	33	17		
Septuple	7	86	71	57	43	28	14	
Octuple	8	88	75	62	50	37	25	12

Double compartments.—Sometimes the compartments should be made of gigantic size in order to meet the efficiency of the factory. Furthermore, in some special working methods, a portion of the vapor is drawn off from the first compartment or the second compartment, which demands that the vapor chamber be of an exceptional size to meet the requirements, and the ultimate result is that their construction offers great difficulty, especially in the case of vertical effects. Some shops prefer to resort to double compartments combined together and acting just as a single. Those double compartments should have a total heating surface as large as if there existed but a single compartment, and the evaporation is to be conducted as a standard apparatus with the same fall of temperature. According to CLAASSEN it is not rational in such cases to introduce into each compartment the juice and the vapor used for heating, by drawing it as is customary from the preceding compartment of the multiple effect. He advises to combine them so that the juice first enters into one section of the double compartment through a large pipe placed at the bottom, and then through the second one, while the steam passes also through both the heating chambers of the double compartment one after the other, but in an opposite direction to that of the juice. By this arrangement the efficiency of the multiple effect is increased, and its practical working kept under constant control, for the reason that the regulation of the height of the juice in the first chamber will at the same time control the level of the juice being concentrated in the other section of the apparatus.

Increasing the heating surfaces.—The splicing of the evaporating compartments of a multiple effect is a plan adopted to increase the heating surface of the standard vertical evaporators. This difficulty is overcome in another way by the LILLIE mode, as shown in Fig. 46. The apparatus consists of two portions, the upper and the lower, and between these semi-cylindrical sections two vertical plates of a length corresponding to that of the apparatus are introduced, between them being placed the necessary number of tubes to produce the desired result. It is to be noted that this method could not be applied to the standard horizontal evaporators, as the level of the juice above the tubes plays an important rôle. The same may be said of vertical evaporators, in which it is proposed to increase the heating surface by leaving a greater space between the tube plates, which means the use of longer tubes. There are

limits as to length of tubes that should not be exceeded. The longer the tubes the greater will be the force with which the juice will be projected, owing to the dilatation of vapor produced, and the entraînement necessarily increases in the same proportion. Practical experience appears to show that two meters in length is the extreme desirable limit. The increased efficiency that could be obtained in such cases is not more than 40 per cent, while by the LILLIE mode the heating surface may be increased 100 per cent. For the horizontal evaporators another solution presents itself.

An evaporating apparatus of the GREINER[1] model consists of a series of elements in box shape, very much the same way as shown in Fig. 55, which are bolted together one alongside the other, so that the size of the appliance may be increased. Each end part has a metal plate that closes the apparatus, and each element has a separate tubular portion, which may be made to connect in one series. All the pipes through which the vapors escape start from the top of these elements and finally connect in one common pipe, which leads into the next compartment of the multiple effect or into the condenser.

FIG. 46.—LILLIE's Mode of Increasing Heating Surface.

Description of different types of multiple effect.—In Fig. 47 is shown the CAIL type of a vertical triple effect, consisting of three compartments, *A*, *B*, and *C*. Steam is introduced into the apparatus through *a* and passes into the calandria or tubular cluster, and the juice is drawn into the first compartment through *d*. The vapors liberated by the boiling of the juice pass through the sugar arrestor, *I*, and then through *D* into the six pipes, *b*, which distribute it to the tubular cluster of *B*. The juice is drawn from *A* into *B* through the pipe *d′*, the resulting vapors pass through the sugar arrestor, *I′*, and through *E* into the six distributors, *c*, of the third compartment. The syrup enters into the section, *C*,

[1] C., 11, 366, 1903.

through the pipe d''. The resulting vapors pass into I'' and G, and then into the condenser, while the condensed syrup is drawn off from the apparatus by a special pump through o, n, m, p.

The condensed water is removed from each of the tubular clusters through the pipes, j, k, l, from which it enters the purger or the ammoniacal water pump. The non-condensed gases are allowed to escape into the open air through the cock, g, from the first compartment where the pressure is greater than the atmospheric pressure, while from the other compartments they escape through

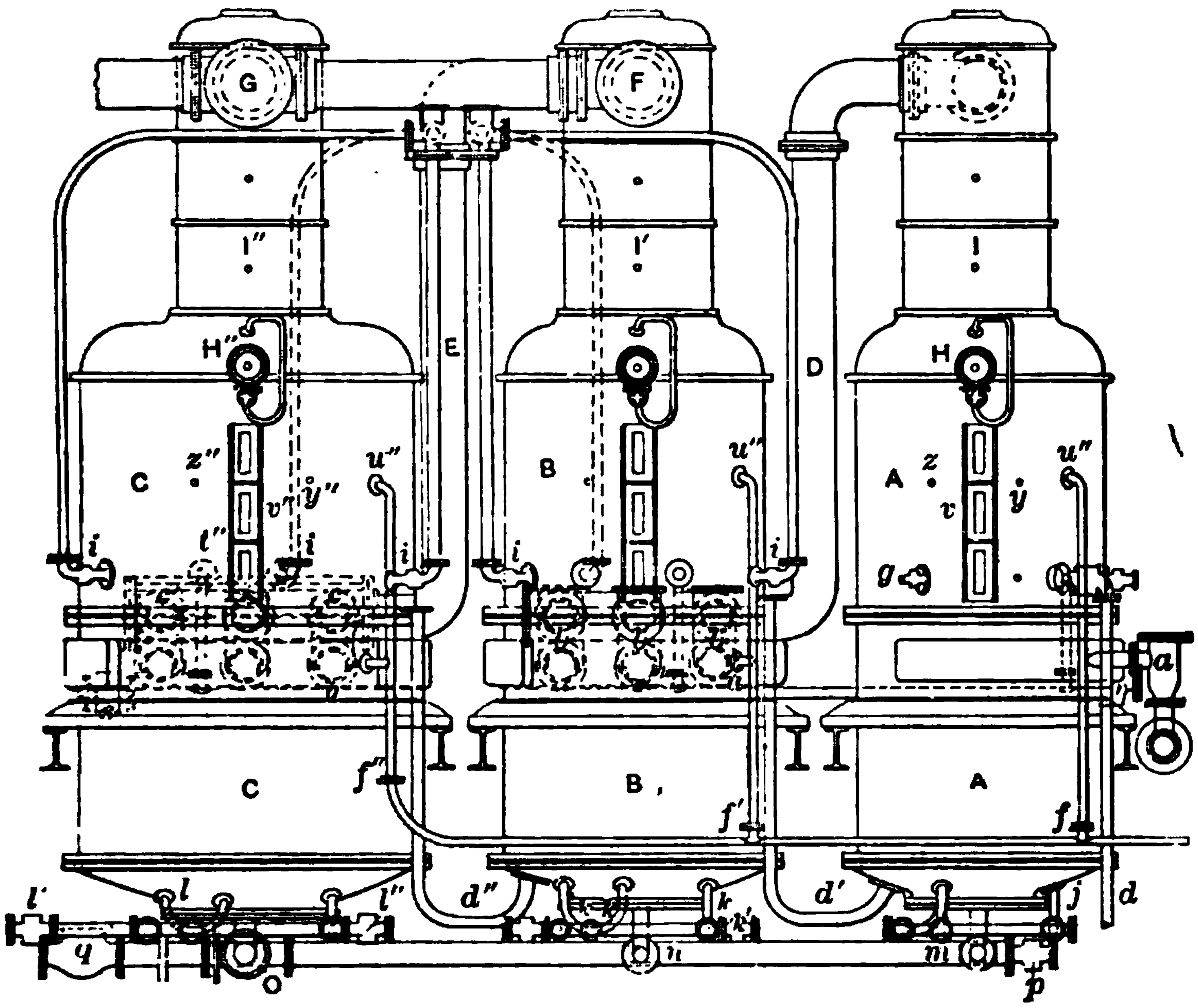

FIG. 47.—CAIL Triple Effect.

the pipes, i, which are all connected with the large horizontal pipe between the valves F and G leading to the condenser. The two valves in question allow the first two compartments to be used as double effects, the vapors of the second compartment being sent to the condenser, leaving the third compartment out of the series entirely.

When it is desired to isolate the apparatus for the purpose of cleaning it the valve G should be closed, the valve F should be opened in the direction of the condenser, and all communication cut off between the second and third compartments by the pipe E.

The pipes, f, f' and ff', will carry the exhaust steam into the interior of the calandria through the pipes, u, so as to thoroughly rinse and clean them when needed. The first compartment cannot be cleaned in this manner. The apparatus may be emptied through the valve q before cleaning. The interior of the juice chambers can be rinsed in the same way by means of the tubes u''.

In Fig. 48 is shown the manner in which RILLIEUX handled the condensed waters of triple effects. Into the first compartment are sent the vapors collected in K, and the waters of condensation of this receptacle run into H. In the tubular cluster of I are also sent, through G and D, the condensed water and a small quantity

FIG. 48.—RILLIEUX's Combination for Condensed Water.

of steam at a high pressure from the coils of the vacuum pan. When the triple effect is not working this condensed water and steam returns into H by G and E'. The condensed water from the first compartment passes through the pipe E and the valve F into H. The ammoniacal waters of the second and third compartments are drawn off by the ammoniacal pump, N, from a special RILLIEUX purger J described under another caption (Fig. 33). The run of the vapors through the apparatus is like that in most multiple effects when working under normal conditions; they pass from I to II, then produce vapors that pass into III, which vapors pass into the condenser, M, connected with the air pump.

It is interesting to examine the Brunswick type of triple effect of most simple construction shown in Fig. 49. The vertical compartments, I, II, and III, are of sheet iron. Steam is introduced through S into the tubular cluster T, in which a large central pipe is placed to facilitate the circulation of the juice. The small pipes,

a, remove the ammoniacal gases at four different spots of the tube plates, the drawing off of these gases being regulated by the cocks, a' and a'', shown outside of the two compartments *II* and *III*. The non-condensed gases are thus carried into the tubular cluster of *II*, where the steam carr ed forward may abandon a portion of its heat. The vapors liberated in *I* pass into *A* and the catch-all *H*, and down through *A'* into the calandria of *II*. The vapors from *II* run in the same way into *III*, from which they pass through *C* to the catch-all *H''* and then into the condenser. The pipe

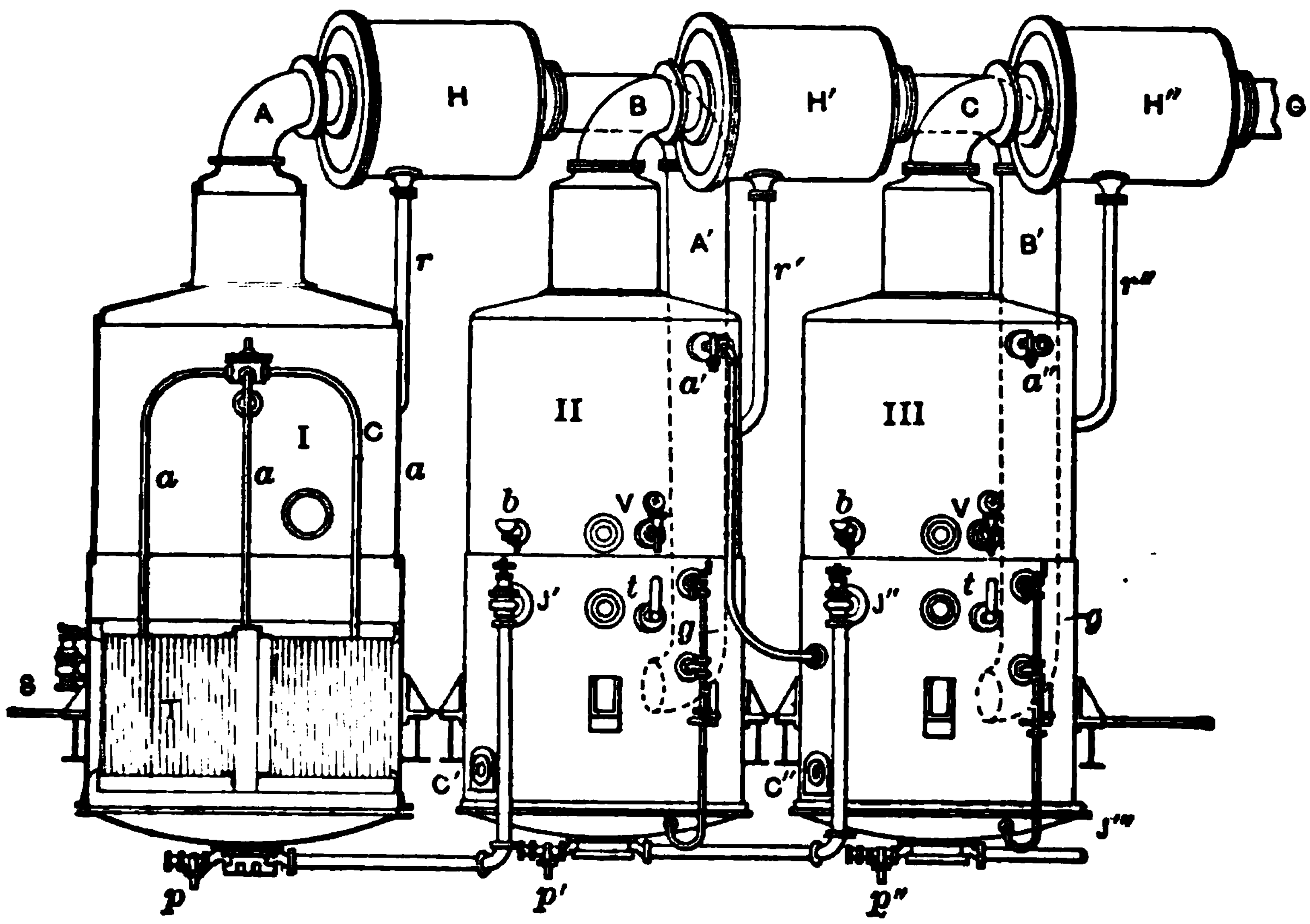

FIG. 49.—Brunswick Triple Effect.

through which the juice enters *I* is not shown in the drawing; but it passes from *I* to *II* and from *II* to *III* respectively through *J'* and *J''*, and the pipe *J'''* takes it to the syrup pump. The condensed water is drawn off through the pipes commencing with the exit opening c' and c''. This apparatus has thermometers, t, juice levels, g, butter cups, b, and vacuum gauges, V. The pipes, r and r' and r'', are for the return of the juice held back by the catch-alls H, H', and H''.

In Fig. 50 is shown the horizontal arrangement as suggested by WELLNER and JELINEK, which has many interesting characteristics. The compartment, *I*, is heated with two kinds of vapors, one at low pressure (exhaust steam) and the other at high pressure (live steam). Each of these vapors enters into separated portions of the

tubular cluster of the first compartment. The live steam enters at *g*, and the exhaust steam by *f* and the valve *h* in the tubular cluster;

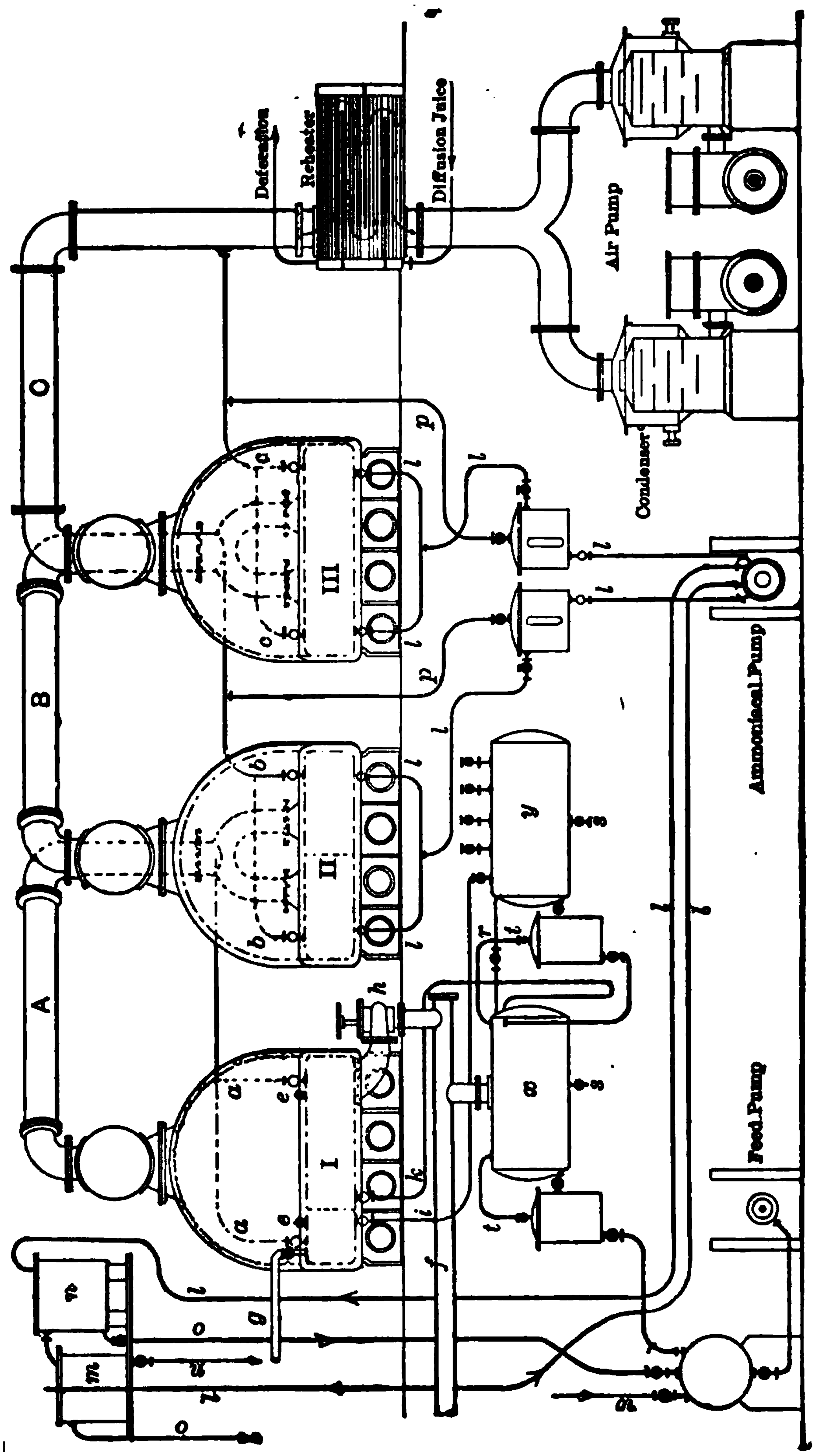

FIG. 50.—Triple Effect, WELLNER and JELINEK Horizontal Type.

ee are exit air cocks, which are left open when the steam is first introduced. At the other extremity these compartments have

ammoniacal gas pipes which join A before it distributes its vapor into the compartment II, and the ammoniacal pipes, b and c, of the other compartments are combined in the same manner. The vapors from III run into the surface condenser, then into the injector condenser, from which the air pump draws off the non-condensed gases. The condensed water from the tubular cluster of I, heated by direct steam, passes by the pipe l into the large collector y, that receives all the condensed water from the appliances heated by means of live steam. The condensed water runs from this collector into a purger which allows it to run into X, used more especially to collect the condensed water from that portion of the apparatus I, which works under low pressure and communicates with that part through the pipe K bent syphon shaped to obviate loss of steam. The condensed waters from II and III are collected

FIG. 51.—YARYAN Triple Effect, End View.

in their respective purgers, which through the pipes ll communicate with the ammoniacal water pumps.

The waters from the second compartment are sent to the tank, m, from which they are taken as needed to various parts of the factory. The waters from the third compartment are run into the tank, n, and from there into the feed-water tank with the waters of x and y, to be pumped back into the boilers. The pipes, p, p, are used to draw off the non-condensable gases that accumulate during the working of the multiple effect or when the apparatus is first started.

The end view of the YARYAN triple effect is shown in Fig. 51. The three compartments are represented by A, B, and C. The vapors run from C through J into the condenser W connecting

with air pump *O*. This apparatus is no longer of special interest as the LILLIE evaporator has taken its place.

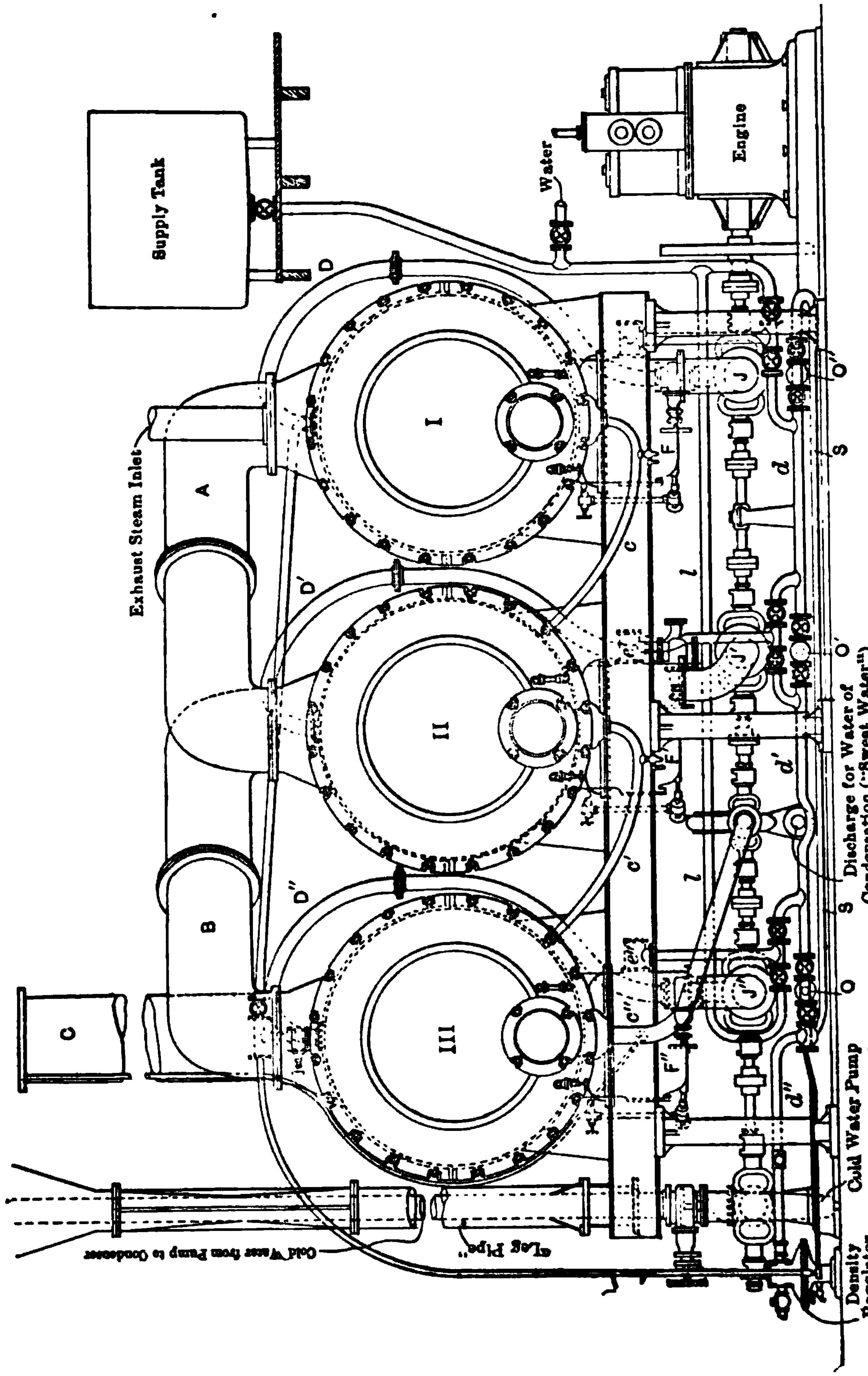

FIG. 52.—General Disposition of the LILLIE Triple Effect.

The LILLIE triple effect (Fig. 52) is made up as follows: The steam used for heating is introduced in front of *I*, and the result-

ing vapors and non-condensable gases pass from the back of the compartment to return in front of *II* through *A*. The vapors in this case pass into *B* in front of *III*, and back of this compartment the vapors run into the condenser. The condensed water from *I* runs into *II* by the pipe *c*, and that from *II* into *III* by *c'*. All this final water is removed by the pipe *C''*. The juice flows from the supply tank into *e* and by a regulated float box, *F*, finds its way into the first compartment through the circulating pump. The working of *F* is automatic—it opens only when the level of *I* is lowered, owing to the passage of a portion of its juice into *II*. The pump, *J*, forces the juice through *D* to the top of the first compartment, from where it flows downward in showers over the evaporating tubes. The pump, *J*, also forces the juice from *I* into the pipe, *d*, and from there through *e'* into the second float box, *F'*. It cannot enter the second compartment until, as in the previous case, the level has been lowered in *F'*. The circulating pump, *J'*, then forces the juice through *D'* to the top of *II*, and when the level in *F''* is lowered it will force the juice through *d'* into *e''*, from where it finds its way into the float box, *F''*. The pump, *J''*, continues to force the juice up to the top of *III*, until the juice becomes a syrup of a density determined upon in advance. The density regulator placed on the pipe, *d''*, will not allow the pump *J''* to force the syrup outside of the apparatus until the desired density is reached.

To prevent incrustations in *III* the juice may be run into *III* through *l* and *e''*, and then into the pump *J''*, but when the level is lowered in the float box, *F'*, the juice runs through *O*, *d'*, and *e'* into the compartment *II*. The same conditions prevail in *I*, the juice passing through *O'*, *d*, and *e*. The syrup passes into *o''* and through the pipe *ss* to the density regulator. In other words, this reverse working means that the thin juice is taken to the coolest effect and drawn off from the hottest. As has been previously pointed out it remains to be seen whether this mode of working can prevent the incrustations with beet juices.

Many efforts have been made to make the evaporating apparatus more compact, in order to decrease the heat losses through radiation, and many combinations have been prepared, but none of them remained long in vogue.

MARIOLLE-PINGUET'S (Fig. 53) apparatus some ten years ago attracted considerable attention. This evaporator consisted of a column made up of three sections three meters high, placed one

over the other, the bottom of which consisted of three double tube plates, *E*, *F*, and *G*. Beneath the lower tube plate, *E*, is a cast-iron basin, *H*, into which is introduced the steam used for

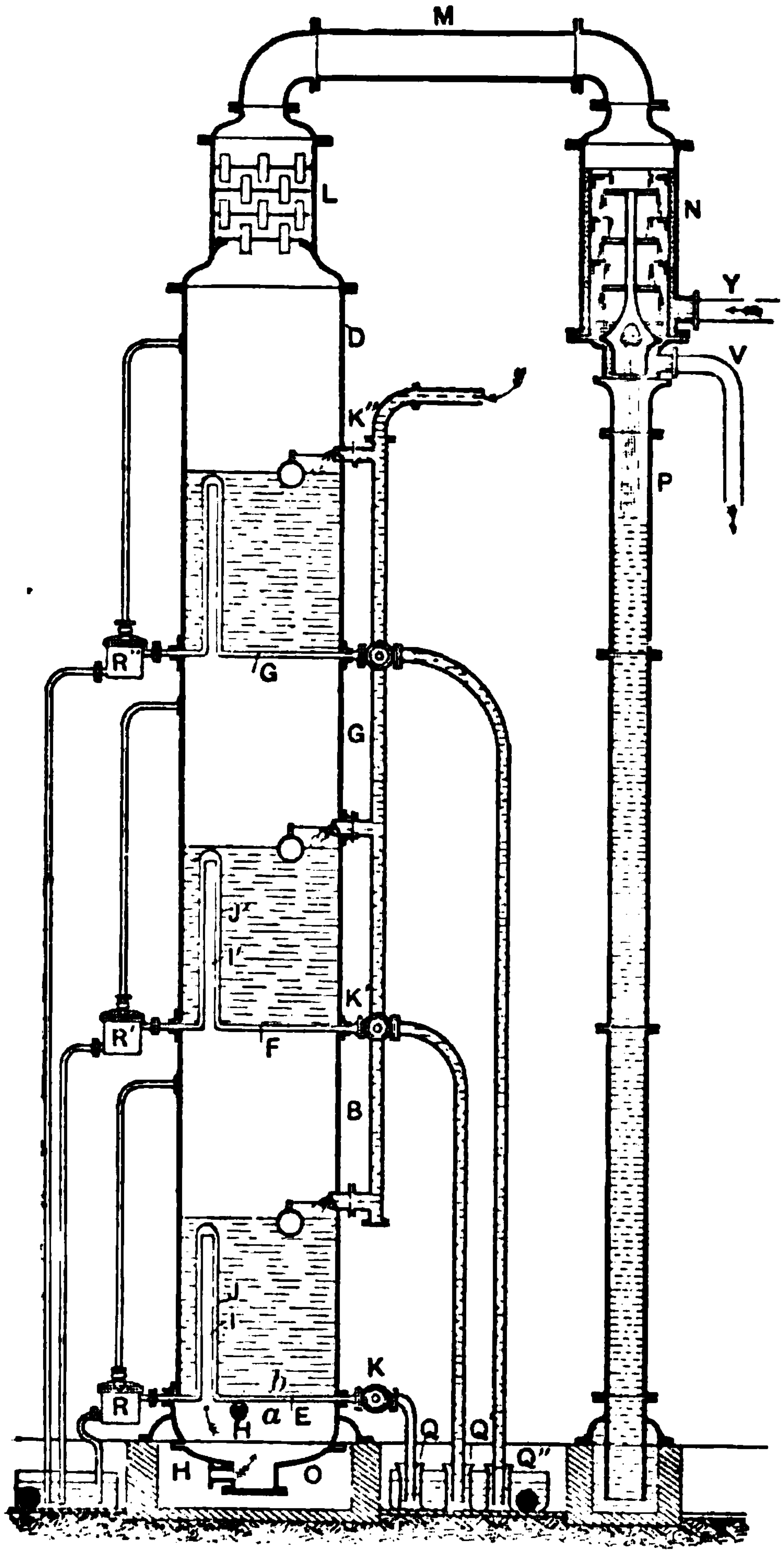

FIG. 53.—MARIOLLE-PINGUET Evaporator.

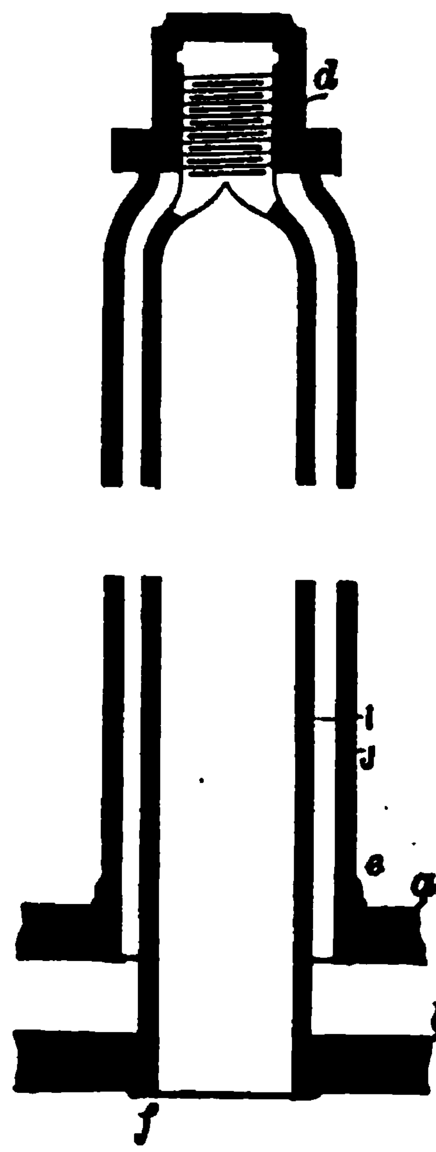

FIG. 54.—MARIOLLE-PINGUET Double Tube.

heating; it penetrates into a series of double pipes (Fig. 54), through the central tube, *I*, and descends in the space left between the tubes *I* and *J*, escaping between the tube plates *a* and *b*. The purger *R* communicates with this space, and only the condensed water is removed through it. The space above the level of the

juice fills the same rôle as does the basin *H* for the first compartment, the resulting vapors heating the second compartment and then the third, etc. Special floats introduce the juice into the three compartments as the evaporation continues. The apparatus has a sugar arrestor, *L*, and a barometric condenser, *N*. Many difficulties have been found in fastening the tubes to the lower plate. The joints of the tubes *I* and *J* were fastened in the plates (*a*) and (*b*), the detail of which is shown in Fig. 54. When (*d*) is tightened the tube *I* is raised and *J* lowered. If the joints, *e*, *f*, are properly made either of lead or rubber the results will be perfect. These tubes may be mounted or unmounted with the greatest ease and may consequently be rapidly cleaned.

This effect upon first examination seems to be very rational and it has been frequently imitated. One of the evident objec-

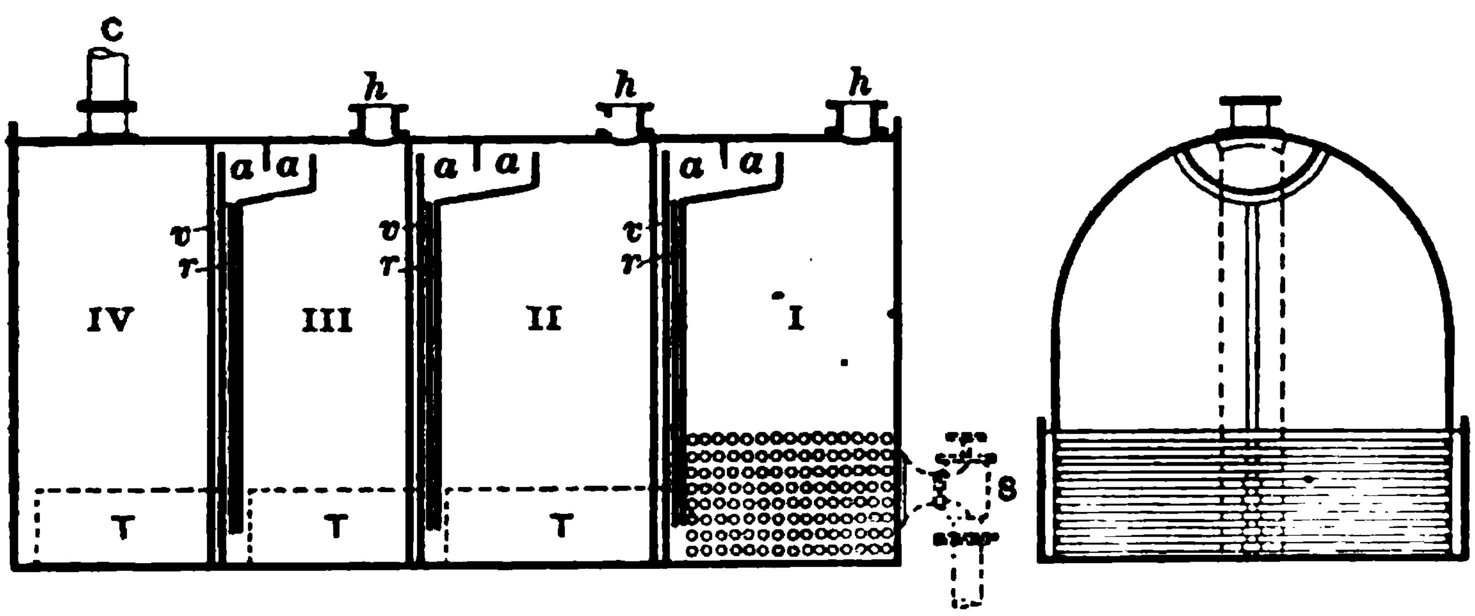

FIG. 55.—WITKOWICZ Quadruple Effect.

tionable features is the difficulty of keeping the apparatus, considered as a whole, under observation, as it necessitates going up and down elevations of six meters in order to inspect the several working parts. In the MARIOLLE PINGUET apparatus each compartment receives the carbonatated juice and from each there is extracted a concentrated juice. Efforts have been made to run the juice from one compartment to the other, circulating either from top to bottom or from bottom to top, but in all such cases pumps are needed, and they always introduce a new complication in the working.

The horizontal multiple effect of the WITKOWICZ type consists of several compartments, *I*, *II*, *III*, and *IV*, shapes as shown in the end view, Fig. 55. The vapors produced in compartment *I* circulate through a sugar arrestor with baffle plates, *a*, then run

downward through *V* along the sides separating *I* from *II*, *II* from *III*, etc., into the tubular cluster *T*. The juice that has been held back in the catch-all returns to *I* by the pipe (*r*). The compartments *II* and *III* work in the same way. The vapors from *III* run into the condenser through *C*. On the top of each compartment are pipes, *h*, from which are drawn off the vapors to be utilized in other parts of the factory.

CHAPTER IV.

THE MULTIPLE EFFECT ACCESSORIES.

Waiting tank for the carbonatated juices.—In nearly every phase of the beet-sugar manufacturing processes there is a waiting tank, and the multiple effect is no exception. As it frequently happens that the flow of filtered carbonatation juice is somewhat irregular the receptacles under consideration render valuable service. The size of the waiting tank should be calculated in advance, so as to meet any emergency that may present itself. As regards large tanks it may be said in their favor that they always allow an important margin in the regularity of the factory's running. But, on the other hand, they have certain objectionable features which must not be overlooked, among them not the least important is the loss of heat, the radiation being proportional to the exterior surface of the tank. The vast volume of carbonatated juice, thus indirectly exposed to the air, will readily ferment, and this always causes decomposition of the sugar and consequently losses. The last, but not the least, objection is that when the volume of juice in the waiting tanks under consideration is very large it takes longer to empty all the appliances of the factory than when they are smaller.

These receptacles should have suitable floats, and the level variations should be shown on scales plainly visible to the evaporating man and the man of the filtration station. They should be kept very clean, otherwise the germs left from a previous juice which had commenced to ferment would contaminate the fresh supply. For the purpose of cleaning manholes should be placed in accessible places. Care should be taken to have the outside of these tanks covered with some non-conducting material and their tops should have suitable covers. Experience shows that there are certain advantages in having steam coils or other devices for heating in an emergency.

Feeding pumps.—When the first compartment of a multiple effect is working under a comparatively slight vacuo or under a comparatively low pressure the juices may flow directly from the waiting tank into the compartment. To accomplish this under the best of conditions the tank should be at an elevation of about two meters above the bottom of the multiple effect. On the other hand, when the pressure reaches a certain point and the flow cannot continue under normal conditions, pumps are needed to feed the evaporating appliance with the juice to be concentrated.

The construction of this pump is of no importance, but it is essential that it be able to overcome the resistance offered by the pressure in the first compartment. WORTHINGTON pumps render excellent service, but, unfortunately, as previously pointed out, they are not economical in their steam consumption. As all such pumps must be readily cleaned they should be easi'y disjointed, their parts should be simple, and suitable pressure gauges should permit one to follow their working. A safety valve is also a very essential accessory, as it permits the juices to return to the waiting tank when the compartment is full and the inlet valve closed.

Exhaust-steam collector.—The exhaust steam of sugar factories is all collected in a special receptacle to be subsequently used, as will be explained under another caption. The shape of such a collector is of no special importance. Into it runs the pipe communicating with the exhaust of all the steam engines, and from it runs another pipe which communicates with the multiple effect, etc. There must in all cases be suitable pressure gauges and safety valves. The safety valves should be regulated so as to correspond to the highest pressure admissible for the working of the steam engines and with the requirements of the evaporator. As a general thing the most desirable pressure is one-half an atmosphere.

As beet-sugar factories are generally located some distance from dwelling houses the noise made by the steam escaping through these valves is of no consequence, but the sound is sufficiently loud for the fact to be taken into consideration, even for the houses of the factory's men. Various means have been suggested to overcome the difficulty. The ANGERSTEIN[1] sound arrestor (Fig. 56) consists of a special shaped pipe, *B*, with a lower branch, *C*,

[1] Jahrb., 1 and 2, 169, 1863.

which is V shaped, with a 50 cm. bend. The vapor or steam enters through *A* and escapes at right angles through the pipe, *B*, which is 5 meters in length. About 40 cm. of water collects in *C*, and this by its up-and-down motion deadens the sound. Another solution consists in allowing the steam to escape through a long conical pipe rising some distance above the roof of the factory.

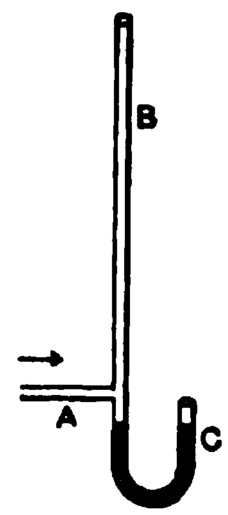

FIG. 56.—ANGERSTEIN'S Sound Arrestor.

The exhaust-steam collector, according to STRAUB, should be sufficiently large, so that the currents created by the different steams collected shall not paralyze one another. Evidently there are numerous advantages in not having them too big, for it is claimed[1] that the exhaust steam direct from the engine still retains the pulsation from its source, and is possessed of a greater evaporating power than a steam would have under normal flow without being backed by the motor. In many beet-sugar factories it is customary to have a special mixing valve attached to the exhaust-steam collectors. The arrangement is such that the live and exhaust steam are thoroughly mixed, which is useful in an emergency, such as occurs when the multiple effect consumes more steam than the engines can supply to the collector. Many experts claim that this idea is a mistake on account of the caloric that is necessarily lost through the expansion of live steam, and to this may also be added numerous other arguments. WALKHOFF[2] recommends that the live steam be entirely separated from expanded steam and that the former be used in separate coils beneath the heating chamber. Under another caption is shown the arrangement that allows this combination. According to HORSIN-DÉON[3] it is advisable to introduce live steam into the first compartment of a multiple effect and not into the exhaust collector. He claims that when exhaust steam comes in contact with live steam the former becomes superheated and will not readily condense. The reverse is the case when they are separately introduced into the evaporator. Just within what limits this theory is correct must be determined by practical experiments. It is

[1] Archief., 3, 222, 1895.
[2] WALKHOFF, Ruebenzuckerfab. IV, 2 156, 1872.
[3] HORSIN-DÉON Traité II, pp. 515 and 587.

always desirable to give a slight slant to the pipe that carries the exhaust steam to the collector, so that the condensed water may flow easily into the receptacle. Experience shows that it is always desirable to have several extra flanges upon the exhaust steam collector, which may be used in case any changes are made in the general plan of the factory's working. Under all circumstances precautions should be taken to give the collector a suitable non-conducting covering.

Syrup pumps.—Some years ago it was customary to draw the syrup from the multiple effects into sheet-iron receptacles from which the air had been removed. When the tank was full air was introduced and it could then be emptied into a syrup waiting tank, from which it was pumped to the next station where the manufacturing process was continued. It is to be noted that this arrangement, which is very simple, had certain objectionable features. A man was needed to give it his especial attention; the air removed passed through the condenser, and this was always followed by a decrease in vacuo; furthermore, there was no possibility of keeping a constant level of the syrups in the third compartment, and this intermittent drawing off caused numerous perturbations in the multiple effect.

The mode of using receptacles for the extraction of the concentrated juice has now become obsolete, for the reason that the syrup cannot be drawn from them continuously. From every point of view preference should be given to pumps, as by their use the drawing off may be done without interruption, which facilitates the regular maintenance of density. In order to overcome the vacuum of the apparatus experience shows that the pumps should be placed at the lowest possible level, under which circumstances the column of juice compensates, at least in a measure, for the action of the vacuum.

Ordinary pumps with double valves are generally used for pumping the semi-concentrated juice from the next to the last compartment of the multiple effects into the sulphuring appliances. On the other hand, for syrups the pump should be of some improved design in order to overcome the vacuum in the last compartment, as perturbations are frequently caused by the valves becoming motionless under the influence of the vacuo—hence the importance of using balanced valves in force pumps. One of the best combinations of this kind is the double-acting pump of HÜBER and ALTER (Fig. 57). When the piston, *E*, works from left to right in

the cylinder *D*, the rubber valves, *A*, are working under suction and the juice enters the pump by the pipe, *z*. To assist this suction a small valve, *C*, opens and places the pump in communication with the last compartment of the multiple effect. During the back stroke the valves, *A* and *C*, will close and the syrup will be forced out through the valve, *B*, and the pipe, *G*. The pump is double in its construction and the arrangement is duplicated on the left and right sides. The closed receptacle, *I*, full of air, communicates with *G* and *G'*, thus forming an air cushion to regulate

FIG. 57.—HÜBER and ALTER Syrup Pump.

the back pressure. The force pipe may be emptied through a special cock in case the pump is not working satisfactorily.

In many factories some good results are obtained with the piston plunger for syrups, but the packing of these soon gets out of order and the pumping efficiency is lessened. In such a case, instead of attempting to excessively tighten the packing, a few drops of water along the outside of the plunger may be used to increase the tightness.

The NEUMANN[1] (Fig. 58) vacuum reducer has met with a certain vogue. It consists of a receptacle, *c*, with a float, *m*, acting on a small valve, *a*, and closing the pipe, *e*, which communicates with the last compartment and creates the vacuum in the apparatus. The vacuum falls in consequence of syrup being introduced, but,

[1] D. Z. I., 25, 18, 1900.

on the other hand, it increases owing to the suction through the pipe, *f*. The vacuum in the apparatus can never fall below a certain limit, and at that instant the suction is the most satisfactory; but as soon as a certain quantity of syrup has been drawn off by the pump the float will open the pipe connecting with the vacuum and allow the syrup to enter until a point is reached when the float will reclose the valve.

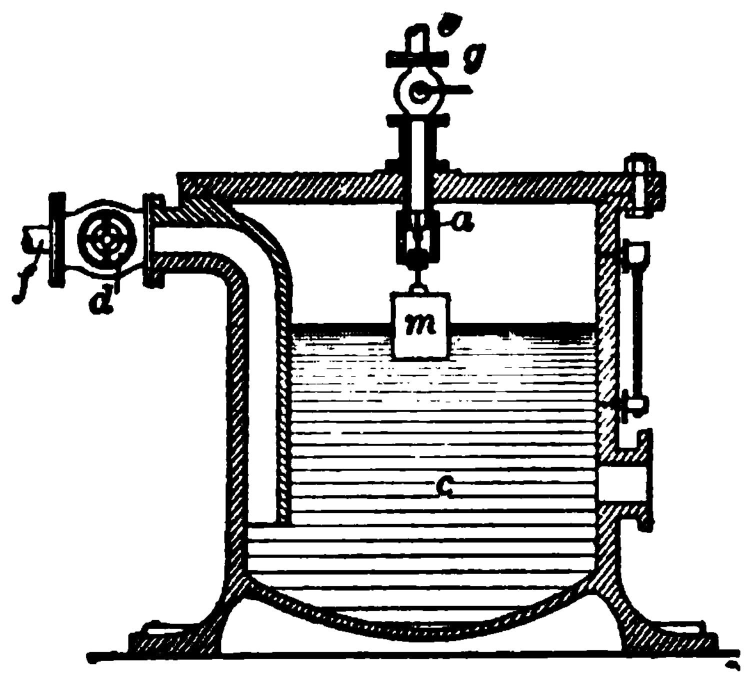

FIG. 58.—NEUMANN'S Vacuum Reducer.

It may happen that for special reasons the syrup pump will cease working and the sound then made gives some indication as to whether the valves are stuck. This difficulty may be overcome in various ways, but the most simple and effectual consists in drawing a certain quantity of air under the valves through specially arranged cocks. Inefficiency may be due to the valves being broken or to deposits on their seats.

CHAPTER V.

CONDENSATION.

FORMERLY, when the double-effect combinations were used, only a small quantity of vapor was utilized either for heating or graining in pan and a considerable volume was condensed. The amount of steam that finds its way to the condenser under existing methods is comparatively small. Whenever one reheats the vapors are evidently condensed, and the reheaters and graining apparatus should be considered as condensers for the evaporation. When the term condenser is used in sugar technology it generally means condensers with injection, whose sole object is to condense the vapors.

The removal of the vapors liberated from the last compartment of an evaporating appliance may be effected in two ways: first, by the use of an ordinary condenser connected with a moist-air pump removing at the same time the injection water, the condensed water, and the gases that have not been condensed; second, by means of a barometric condenser connected with dry-air pump, which removes only the gases that have not been condensed, while the condensed water and injection water freely evacuate at the lower end of the barometric column of the condenser.

Total steam to be condensed.—CLAASSEN calculates that with a multiple reheating of the juice with vapors of evaporation, and the evaporation in a quadruple effect of 100 kilos of water for 100 kilos of beets, only 10 kilos find their way into the condenser. It necessarily follows that the caloric contained in these vapors to be condensed is lost, and efforts continue to be made to find some practical mode of reducing the loss to a minimum, one of which is the use of tubular reheaters through which these vapors circulate, thus transmitting at least a portion of their heat to water, juices, etc., which may be used during some subsequent phase of the sugar extraction. In these reheating appliances a condensation necessarily takes place, which is that much less work to be accomplished in the condenser proper. The 90 kilos remaining are condensed

either on the heating surfaces of the evaporating appliances, vacuum pans, or reheaters, and are recovered in the form of nearly pure water, containing a fraction of ammonia.

Besides the vapors from the multiple effect there remain to be condensed those from the vacuum pan. After the syrups leave the effect and enter the pan there must be removed 10 to 15 kilos of water for 100 kilos of beets sliced. The evaporation in pan differs from that in the last compartment of the multiple effect in that the operation there is regular, while in the vacuum pan it is very variable. Such being the case, the installation of the condenser must not be calculated upon a basis of average evaporation, but upon the maximum volume of steam to be condensed at a given moment.

The condensing installation consists mainly of the injecting condenser and an air pump. Besides these there are a few other appliances, such as the apparatus supplying the water, and those which permit this water to be again used in the factory when there is a scarcity.

Condenser.—With the exception of surface condensers—already described under the caption Reheaters—the shape of the condenser depends almost entirely upon the type of air pump used in connection with it. There are many combinations and the actual variations are based upon the manner in which the water of condensation comes in contact with the vapors to be condensed. Most of the existing combinations possess some characteristic and rational feature. Only a few of them can be mentioned here.

It is generally admitted that these appliances should have interior arrangements by which the contact of the injected water and vapors occurs on the largest surface and during the longest period possible, and it is also desirable to use counter currents to force the water and the vapor to flow in opposite directions, thus obtaining a maximum condensation with a given volume of injected water. However, the arrangement generally used to effect a perfect contact presents certain difficulties not easily overcome in practice. Upon general principles it may be said that the passage in the diaphragms of a condenser should be such that the pressure exerted upon the descending waterdrops by the rising steam will never exceed their weight. EHRHARDT[1] declares that it is a great mistake to arrange a condenser with baffle plates and perforated disks. He

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[1] C., 3, 770, 1895.

maintains that even in the most primitive type of condensers water is absolutely pulverized and possesses a large surface of contact, without the necessity of making use of many of the modern appliances in which the diaphragms soon become covered with lime deposits, especially when the water used is charged with calcic salts.

According to Weiss[1] there is no necessity for any appliances distributing or sprinkling the water of injection in the counter-current injectors. As soon as water is more or less subdivided the object in view is realized, especially when the water is circulating at a certain velocity, for there then follows sufficient motion in the mass of vapor to be condensed and all the particles are brought several times in contact with the surface of the water, so that the condensation is immediate. The moving water molecules are constantly renewed upon the surface; through their immediate contact with the vapors they will absorb its caloric and return into the mass of liquid permitting other water molecules to reach the surface.

The gas that will not condense consists mainly of air, and contains a certain volume of watery vapor which escapes the action of the injected water. Do what one may, the air cannot be done away with by condensation; but it is possible to considerably reduce the volume of non-condensed gases by the contact of the vapor with cold injection water. In order to accomplish this the condensers should have sufficient capacity and be established upon a rational basis. According to Cambier,[2] while no rule can be given as to the most desirable capacity of a condenser, it should, upon general principles, be made large, so as to avoid an accumulation of non-condensed vapors when the piston is at the end of its stroke, and consequently when its velocity and its efficiency are reduced.

Parallel-current condensers.—These are still used in some factories where moist-air pumps are in vogue. The water and the non-condensed vapors are drawn into the cylinder at the same time. The most simple forms of condensers are used, consisting usually of a cast-iron cylinder. The vapors introduced on top are condensed by coming in contact with cold water projected from a spraying device, which has the objectionable feature of becoming clogged and after a time ceasing to give satisfaction.

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[1] Weiss, Kondensation, p. 83, 1901. [2] S. I., 41, 291, 1893.

In order to give the vapors a longer time to condense the water should have a considerable run in the condenser by passing over a series of steps as a cascade. In the parallel current condensers the hottest vapor comes in contact with the coolest water, yielding up its caloric to the water, and upon reaching the bottom the temperature corresponds nearly to that which would result from a mixing of water and vapors. In these types of condensers it is impossible to ascertain how the apparatus is working and whether a poor vacuum is due to a faulty distribution of the water, or to some defect in the multiple effect, etc. In most cases the air pump has not the efficiency expected of it, and does not exhaust from the condenser the comparatively hot non-condensed gases.

The arrangements or combinations that have come in vogue from time to time have been most varied, and the variations are such that a complete description of them would carry us beyond the limits of the present writing. The JELINEK type (Fig. 59) has held its own and should be described. It consists of two concentric cylinders, *A* and *B*. The outer one has a cover with an upper opening *D*, through which the vapors to be condensed enter. The inner compartment has a series of partitions, *C*, forming with the disks, *E*, alternate obstructions to the descending water. These are circular and are held in position by a vertical bar. The water is injected through *F* into the annular space, and rises to the upper level of the cylinder, *B*, into which it overflows through *G*. Through this same opening pass also the vapors to be condensed. The water falls from the baffle plates to the bottom of the apparatus, and during its fall is brought in contact with the steam or vapor which continues its flow as shown by the arrows. The products of condensation and the gases that cannot be condensed are drawn off through *H*.

Another type of condenser by the same inventor (Fig. 60), known in France as "débourbeur," is of special interest and renders excellent service when the water is charged with mineral substances which are likely to deposit and form obstructions in the condenser and air pumps. It consists of a rectangular compartment having an upper tubular orifice, *A*, for the entrance of the vapor to be condensed. The injected water enters at *B*. The lower tube, *C*, connects with the suction air pump. At regular intervals in this condenser are horizontal partitions with perforations, *D*, these openings alternating on each horizontal layer,

each having a raised border. The mixture of injected water and vapor passes over their border and through their section, and finally reaches the bottom, depositing its suspended impurities during the flow. When the small drawers are filled with deposits they may be removed through an opening on the side of the condenser, and replaced by fresh ones.

In Fig. 61 is shown a parallel-current condenser, as described by HAUSBRAND,[1] in which the water pulverization attains a considerable extent. The efficiency in this case should be nearly

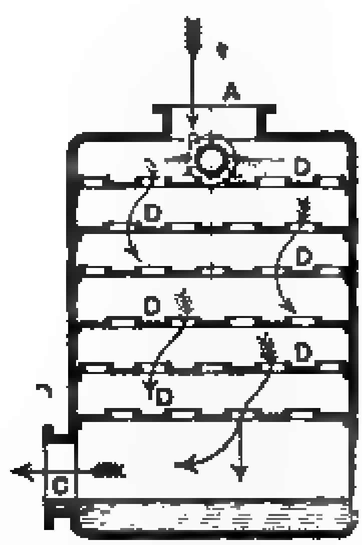

FIG. 59.—JELINEK Condenser. FIG. 60.—JELINEK'S "Débourbeur." FIG. 61.—Spray Condenser.

theoretical. It consists of an iron cylinder, C. The vapor to be condensed enters by the pipe, V, and passes through a shower of cold water introduced into the apparatus through the valve W, and the tube, T, with upper perforations. The water and non-condensed gas escape at E.

Counter-current condensers.—The apparatus now generally used as condensers are with counter currents. The vapors of condensation enter at the bottom and are brought in contact with water flowing in on top. When first introduced difficulties occurred and condensers with parallel currents came into vogue, but their working is not rational. The accumulation of water in the condenser of the counter-current type caused the water to be carried by entraînement into the air pump. This difficulty has been overcome by simply giving to the condenser a greater height, using

[1] HAUSBRAND, Evaporating, p. 210, 1903.

dispersing appliances made up of perforated sheet iron, etc., for the water. Counter-current condensers made in this manner work without perturbation. These apparatus give general satisfaction, for the reason that when sufficient cold water is injected a vacuum of about 60 cm. can easily be produced which gives the best results. As already explained, there is no need, for the purpose in view, to exceed this limit, which gives satisfaction both in the multiple effect and in the vacuum pan.

Upon general principles it may be said that for all heating and cooling appliances the combinations should have opposite currents. The cooling medium in this case may flow off at a temperature only a fraction lower than the highest temperature of the product to be cooled. In parallel currents the cooling fluid runs off at a temperature corresponding to the lowest temperature of the vapors being condensed. The consumption of water for counter-current condensers is very much less than for parallel currents, and this is a very important fact to consider in case of scarcity of water in a sugar plant. To which consideration may also be added. the very important issue of less power being needed as less water is pumped into the condenser. What is especially interesting regarding the effects of condensation by the two modes is that their efficiency depends upon the quantity of non-condensed gas held in suspension. The smaller their volume the less will be the difference between the quantities of water needed to obtain the same vacuo when comparing parallel- with counter-current condensers, while if there were no non-condensable gas the water consumption would be the same in both cases.

In the case of counter currents one may always be sure that the cooling action of the water used is satisfactory when the temperature of the exit flow corresponds to the existing vacuo in the multiple effect. In this arrangement the coldest water first comes in contact with the vapors that are reaching their limit of condensation. During its circulation the water increases in temperature and reaches its maximum when coming in contact with the vapors upon their entering the apparatus. The arrangement of the diaphragms is generally such as to bring about a cascade of the down-flowing water, or by means of simple perforated sheet-iron disks to allow the cooling liquid to drop through, but in such cases precaution must be taken to prevent clogging by deposits of particles in suspension, this being done by the use of wire cloths. Weiss[1]

[1] Weiss, Kondensation, p. 83, 1901.

points out that the most primitive condensers give an excellent vacuum, for the reason that the time needed for condensation is very short and all complicated devices or combinations are unnecessary.

In the SCHULTZE condenser (Fig. 62) water is subdivided so as to fall as a shower. The vapors to be condensed enter the apparatus, K, through the lateral pipe, B, and a first cooling is effected when they come in contact with cylinder, C. They continue a downward course and enter the interior of C at P, rise and come in contact with the water shower, during which period condensation occurs. Water is introduced through the pipe, W, and after reaching the perforated disk, N, passes through small pipes fixed in the disk, which act as overflows, their height depending upon their distance from the centre axis of the distributing plate. Under these conditions the shower represents a considerable condensing surface, even when there is very little water. The non-condensed gases are drawn off by the air pump through the pipe, L, and the condensed vapor and water run off at F. The general arrangement of this apparatus permits the removal of the disk, N, and even of C—which is simply suspended in the condenser—when it needs cleaning.

FIG. 62.—SCHULTZE Condenser.

The GREINER condenser (Fig. 63) is upon general principles very much the same in its construction as the type just described. The vapor enters the condenser, C, through V, and comes in contact with G, rises through the shower of water, and thus condenses almost entirely. Water is introduced through W, and upon reaching the top spreads itself out on the perforated plate, T, and showers into the condenser. The non-condensed gases pass through the perforated plate, and flow through A into the water separator S. This is an excellent device which prevents the water carried by entrainement from reaching the air pump, instead of which it runs off through P'. The pump draws off through A' the air liberated of its water. The

FIG. 63.—GREINER Condenser.

arrangement offers especial advantage when there is an accumulation of water upon the sieve, *T*, which may be due to clogging by the deposits either of particles in suspension or of the lime held in solution. The cleaning may be done through the manhole, *M*. It is desirable in such cases to have an extra perforated plate, one being placed in position during the cleaning of the other.

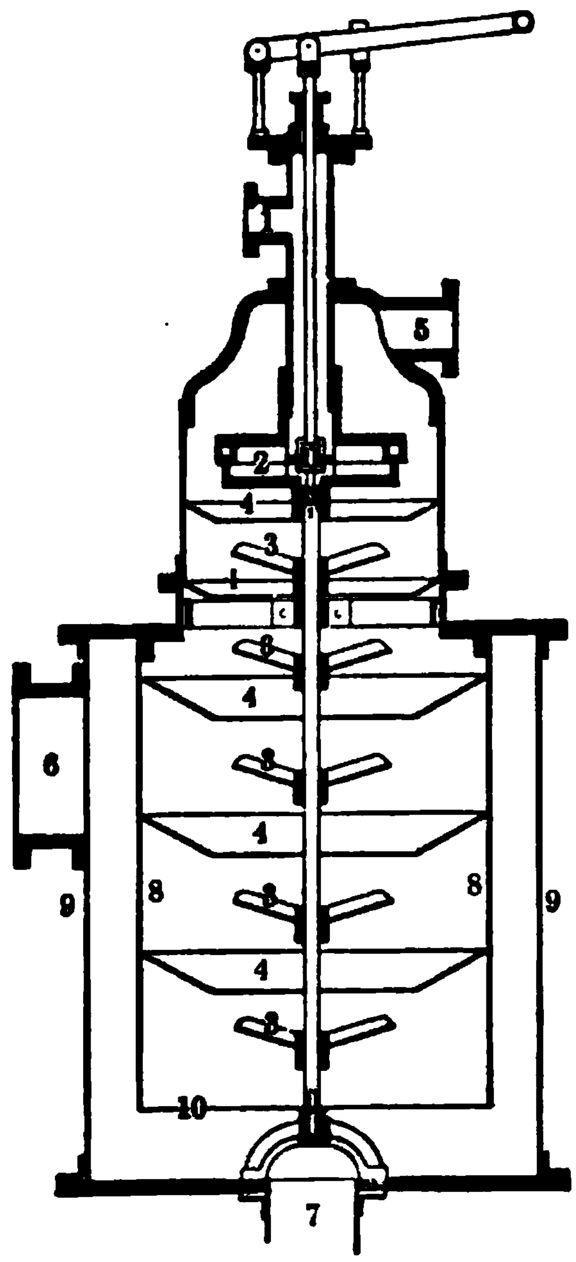

FIG. 64.—KETTLER Condenser.

In the KETTLER condenser (Fig. 64) water is introduced at 1, enters into the water turbine, 2, and is projected as a fine spray against the sides of the apparatus; it collects in plate 4 and flows upon 3, from which, owing to its rotating motion, it is projected, etc. The motion of all the revolving portions, 3, is received from the turbine, 2. Water thus is repeatedly pulverizated from top to bottom of the apparatus, and runs off through the barometric pipe, 7. The vapors to be condensed enter at 6, and passing by 10 through the condenser rise successively through all the strata of water and condense. The non-condensed gases are drawn off through 5 by the air pump. The efficiency of the turbine, 2, is regulated by a lever placed on top of the apparatus.

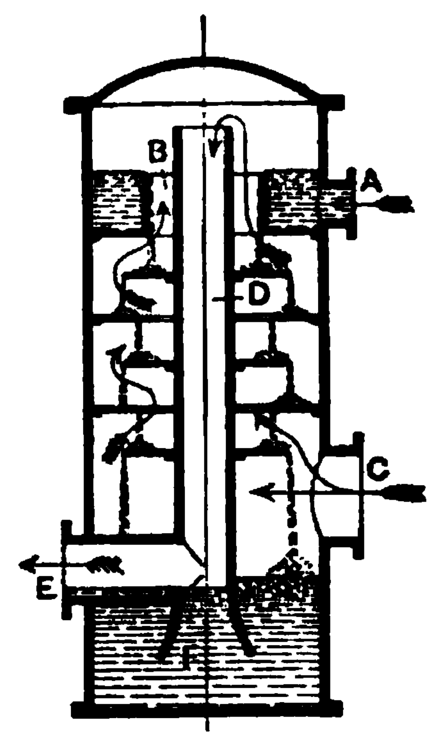

FIG. 65.—ST. QUENTIN Counter-current Condenser.

The counter-current condenser of the ST. QUENTIN type, very much used in France, is shown in Fig. 65. The injected water enters at *A*, and falls over the obstruction, *B*, rebounding from plate to plate to the bottom of the apparatus. During these successive falls it meets and condenses the vapor from the multiple effect which enters at *C* and is drawn, as shown by the arrows, toward the central tube, *D*, forming part of the horizontal piping, *E*, which connects with the air pump. The condensed water accumulates at the bottom and runs off through the continuation of *D* and *E* into the suction chamber of the pump.

The SCHWAGER (Fig. 66) type of condenser has met with some favor, and consists of a vertical cylinder, C, in which is attached upon an angle iron support, H, a vertical pivot, D, holding segments of sheet-iron circles, placed one over the other in the form of spiral steps. Cold water from a reservoir, A, is introduced at b, and distributes itself successively upon all the plates, i, forming a perfect cascade from top to bottom. It is evident that the efficiency of this arrangement by which the surface of water is brought in contact with the vapors entering the apparatus at V is very satisfactory. The water and condensed vapors run off at P, and the air escapes at E in the direction of the pump. The plate, F, prevents any water entrainement. In case of an insufficiency of cold water warm water may be drawn up through b and allowed to enter the apparatus through the pipes, b^1 and b^2, resulting in a subdivided condensation. This warm water condenses an important part of the vapors. The condensation is completed upon reaching the upper layers of cold water.

FIG. 66.—SCHWAGER Condenser.

In Fig. 67 is shown the method of combining a moist-air pump with a counter-current condenser. It is well understood that in such cases the non-condensable gases and the water should leave the condenser separately. By the SCHIFFNER[1] method the air is removed from the condenser through the pipe, C, and the condensed water through the pipe, E. These are combined in the pipe, B, before entering the air pump, D. In this case water is injected through W, collects in a basin, and gradually overflows into a series

FIG. 67.—SCHIFFNER'S Combination of Moist-air Pump with a Counter-current Condenser.

[1] Oe.-U. Z., 17, 761, 1888.

of shallow troughs placed one over the other. The water flowing from one step to the other forms a sort of curtain through which the vapor to be condensed must pass in order to reach the top of the apparatus. It seems, however, that the gases upon their mixing in the air pump with this hot water would expend and reduce the efficiency of the pump.

To increase[1] the efficiency of parallel-current condensers the vapors, in some cases, upon leaving that apparatus run through a counter-current condenser which completes the condensation or at least yields more satisfactory results than would be possible in the first-mentioned apparatus. This arrangement is shown in Fig. 68.

Fig. 68.—Modification of Parallel-current Condenser.

The water of injection is projected in a finely divided condition into the interior of the condensers, C and C_1, through the pipes W and W_1. The vapors are introduced into the condenser, C, through D, travel in the same direction as the water, and then pass into the counter-current injector, C_1. The non-condensed gases are drawn off through E. At the bottom of each condenser the condensed vapor and injection water collect.

Other modes. — Numerous methods have been proposed to reduce as much as possible the volume of water used during condensation. Many years since Degrand[2] proposed that surface condensers be used in sugar factories. Such methods would evidently effect an important saving in water and consequently in motive power, but would demand costly refrigerating appliances. Jelinek proposed that the Theisen (Fig. 69) device be used. The vapor to be condensed enters through b into a tubular cluster, l, which is submerged in the refrigerating water. Several circular, tin-lined iron disks, e, revolve in the cooling liquid and carry on their surface a thin layer of water. On these disks air is circulated by the fan, k. The evaporation of a portion of this water is sufficient to keep the entire liquid very cold. The

[1] Weiss, Kondensation, p. 64, 1901.
[2] Péclet, Traité IV, 2, 347, 1878.

condensed water from the tubes escapes through c at the same time as the non-condensed gases.

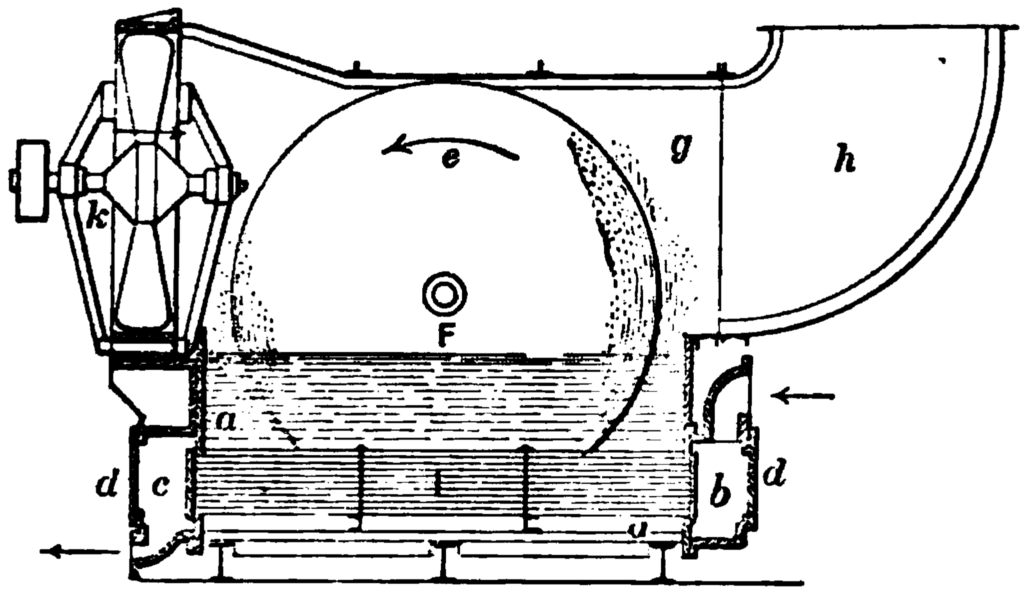

FIG. 69.—THEISEN Condenser.

Barometric condensers.—It has already been pointed out that the moist-air pump removes at the same time the water and the non-condensed air. On the other hand, the dry-air pump removes only the non-condensed gases. Consequently, in combination with these, there is needed some special arrangement by which the enormous volume of water needed for condensation may be rapidly carried off. Evidently regular pumps might in a manner overcome the difficulty, but experience shows that there are numerous advantages in adopting mechanical means which are more economical and equally satisfactory. For this purpose the so-called barometric column is utilized.

It is a well-known fact that if a pipe of sufficient diameter and length passes from the bottom of the condenser into a tank of water at a depth of 10.33 meters, by removing every particle of air in the interior of the apparatus the pressure in the condenser will be reduced by a quantity corresponding exactly to a column of 10.33 meters of water, and the water from the tank below will rise to the upper part of the tube and thus represent one atmospheric pressure. Any volume of water introduced into the condenser will run out from the bottom of the tube in quantities corresponding to that added, and the upper level will consequently always remain the same. Evidently one of the essential conditions for the satisfactory working of the barometric column is that the degree of vacuum in the condenser remain constant, otherwise some perturbations would necessarily follow. The non-condensed gases must be removed, or they would accumulate and exert their pressure, and the equilibrium between the inside and the outside of the tube would no longer exist. Efforts have been

made to demonstrate that the work expended in pumping the water up to the top of the column-barometric condensers is comparatively small for the results obtained. A simple calculation would show that this power is less than that needed to remove the water by an ordinary moist-air pump.

A column-barometric condenser generally consists of a counter-current condenser, a barometric tube for the exit flow of water,

FIG. 70.—Barometric Condenser.

and an air pump for the removal of the non-condensable gases. This kind of condenser was invented by DAVIS [1] in 1829. According to WALKHOFF this system was introduced in the sugar manufacture by BORSIG.[2] The general arrangement is shown in Fig. 70. In the last compartment, *A*, of a multiple effect the vapors are directed through *B* into the condenser, *C*, which has

[1] Sugar Specifications, No. 5785, p. 39, 1871.
[2] WALKHOFF, Ruebenzuckerfab. III, 531, 1867.

an interior casing, D, into which the cold water is injected by means of a perforated pipe. The lower portion of C is conical in shape and terminates in a long pipe, F, which is called the barometric column. The lower portion of this pipe plunges into a cistern, G. The condenser, C, toward the upper annular portion formed by D, has a connection, H, with the pipe, I, of the dry-air pump, J. The vapors from A condense in D when coming in contact with the injected water, and the resulting condensed water falls to the bottom of the condenser and runs through the barometric pipe into the cistern, G, having an overflow at K. The non-condensed gases liberated from the water of condensation are drawn off by the air pump, J, and by the back stroke of the piston are thrown into the air. Owing to the vacuum that prevails in the condenser, C, the atmospheric pressure acts on the surface of the water in the cistern, G, and forces it to rise in the barometric column, F, where it is held up to a height, h, this latter representing in meters of water pressure the difference between the atmospheric pressure and the vacuum existing in the apparatus, increased by the charge necessary to produce the flow of water at the bottom of the column, so that under an approximate vacuum of 66 cm. of mercury in the condenser, the height, h, will be about 9.50 m. This explains why a minimum length of 10 meters is allowable for the barometric column, F. To be on the safe side it is better to have it 12 meters, then the oscillations in the height of the column of water, which are frequently more than a meter, need not be dreaded.

It is very important that the barometric tube have a considerable diameter, more particularly when using water that is likely to leave calcareous deposits. Under these circumstances there need be but little apprehension that the pipe will become clogged. The apparatus cannot be cleaned during the campaign, as this would mean a general stoppage of many of the important pieces of machinery used, which must work incessantly from first to last. The water injected into the condenser, C, is drawn off by the pipe, L, from the tank, M. The arrangement demands a cold-water pump to keep M nearly full, or if necessary running into the barometric condenser. The level of water in the reservoir, M, may be kept constant by the use of a suitable float and a sudden rush of air through L, in case of insufficiency of water, would thus be obviated. This should in all cases be avoided, as accidents of various kinds might follow. The air

pump could, for example, burst if its exit air ports were not of sufficient size to meet the emergency.

Working of the condenser.—As has been previously pointed out the essential conditions for the satisfactory working of a condenser are that nearly a perfect vacuum be maintained in its interior, and that the volume of water used be kept within reasonable limits, as, if there is not sufficient water, the vapors cannot be satisfactorily condensed and what remains would be drawn off by the air pump at the same time as the non-condensable gases. This would necessarily mean more work for the pump and a waste of steam, and, furthermore, its efficiency being lessened, the vacuum obtained would run below the normal. Evidently an excess in the other direction is to be avoided, that is to say the use of more water than is actually needed. When moist-air pumps have to draw off an excess of water they leave behind a certain volume of the non-condensed gas, and there follows a decrease in the vacuum.

Upon general principles it may be said that the volume of water to be injected should be proportional to the vacuo one wishes to obtain. A simple way of determining whether the volume of water circulating in the condenser is in excess is to place one's hand on the exit pipe, which should always remain warm and should never be cold. MALANDER points out that in the case of parallel-current condensers it is very difficult to ascertain what the temperature of the exit flowing water should be, the vacuum being governed by the temperature of the injected water.

It is important to note that excessive vacuum in a condenser is not essential in any phase of beet-sugar extraction. According to CLAASSEN a condenser may be considered to be working in a satisfactory manner when the vacuum is 60 cm., when the water of condensation runs off at a temperature not more than 10° C. lower than that of the vapors of evaporation, and, furthermore, when the gases entering the pumps are cooled so as to be at the same temperature as the water of injection. In order to have the working of the condenser under proper control it is recommended that thermometers be placed on the barometric tubes of the condenser and on the suction pipes of the air pumps. Variations of temperature will indicate the existence of irregularities, such as too much or too little water of injection.

Perturbations in the working of condensers.—Difficulties present themselves when the desired degree of vacuum is not attained

in the condenser, the causes for which are numerous. If air enters the apparatus the vacuo is lessened. If the leakage is considerable it can easily be detected, as it will then be heard. When smaller the flame of a candle should be placed near the suspected joints, and its change of direction will give practical evidence that there is an inward flow. All joints of manholes should be kept very tight by frequent tightening of bolts, suitable calking with putty, etc. As has been previously pointed out the insufficiency of water in the condenser is generally responsible for the decrease in the vacuum. A clogging of the spraying device is frequently sufficient to bring about this perturbation.

Attention has already been called to the desirability of having perforated diaphragms for the condenser in reserve, so that they may be changed without any delay in the working of the apparatus; but, anyhow, it necessitates stopping the air pump, which means to stop also the working of the multiple effect and the vacuum pan. It may also happen that the barometric column becomes clogged through calcic deposits from water abnormally charged with lime, but this danger is very little to be feared during the short period a beet-sugar campaign lasts. When all the other appliances are submitted to a cleaning, however, it is better to include this pipe also.

Entrainment of water from condenser.—For some reason, for which no scientific and satisfactory explanation has yet been found, water finds its way from the condenser into the multiple effect and vacuum pan. VON LIPPMANN[1] maintains that this entrainment is due to faulty calculation in the relative proportions of the air pump and the condenser. If the air pump is too large it has a tendency to draw the vapor from the lower to the upper surface of the condenser; furthermore, it tends to bring the vacuum to a degree higher than that corresponding to the temperature of the water of condensation, under which condition the water may begin to boil in the barometric column. The mixture of vapor and water thus obtained is lighter than water and may be carried above the barometric tube. When the bottom water receptacle, in which the column terminates, is small it might under these conditions be entirely emptied. In order to prevent the perturbation under consideration the revolutions of the pump should be lessened. With the same idea in view,

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[1] D. Z. I., 28, 59, 1903.

suitable valves, which close when there is a sudden tendency for the water to rise in the column, may be placed at the bottom of the barometric column. However, it is to be noted that these valves are objectionable, in that they no longer work when covered with lime deposit.

EHRENSTEIN claims that the cause of this entrainment may be attributed to the principle of counter-current condensation. To overcome[1] the difficulty he proposes to use a condenser with parallel currents and to complete the operation in a surface condenser. EHRHARDT[2] states that water falling from one baffle plate to the other has a constantly increasing temperature and when reaching the bottom of the condenser it boils; the resulting steam tends to rise, obstructs the passages intended for the water of injection, and then is carried into the pipe connecting with the air pump, or that in communication with the vacuum pan or multiple effect.

A well-known authority[3] points out that in the waterfall condensers the vapors and the gases should pass through falling water before reaching the condensers, and this causes an accumulation of water above each of the obstructors. If the passages for the vapor are too narrow the water forms a column which prevents the vapors from passing and the vacuum falls in the evaporating appliance. There results more or less difference between the vacuum at the top and bottom of the condenser and the particles of air that fight their way through the column of water carry with them as far as the air pump some water, unless precautionary measures are taken to prevent this during its passage. However, the water will continue to accumulate until its hydrostatic pressure overcomes that of the vapors of the multiple effect; the water will then fall by gravity. Where this water accumulates the air pump can more readily draw it off when combined with air bubbles or gases, which make it lighter, and it consequently passes into the air pump.

Central condensation.—As previously pointed out the perturbations in the working of the condenser frequently result in a disturbance in the general manufacturing processes. The operations of the multiple effect and vacuum pan come to a standstill, and the natural result of such conditions is an effort to devise some way of overcoming the difficulty. One of the best solutions,

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[1] C., 11, 523, 1903. [2] D. Z. I., 28, 59, 1903. [3] Z., 53, 443, 1903.

of course, is to keep the condensers of the multiple effect and those of the vacuum pan entirely separate, but it presents many inconveniences. Numerous plans have been suggested. It is possible to combine several condensers with one central air pump. The most practical solution is, however, a central condenser combined with a central air pump of corresponding dimensions, under which circumstances the working will be more economical, there will be less water consumed, and the general work will be much simplified. The objection found to this mode is that it is difficult to prevent leakage in the large valves connecting with the evaporation chambers and allowing to isolate them when necessary.

Furthermore, it is said that the graining of syrup in pan cannot be as satisfactorily accomplished with a constant vacuo, as when the pan man can regulate the vacuum by injecting more or less water into each of the isolated and separate condensers. This last objection is not tenable, for the reason that with experience the pan man can obtain the same results with a regular as with an irregular vacuo. Possibly when one wishes to obtain special grades of sugar, such as very large crystals for special usage, a separate condenser offers some advantages, and the regulation is easier than it is with a valve connecting the pan with the condenser.

Valves having conical seats of vulcanized fibre, as they are now made, give satisfaction and will undergo but little change during the sugar campaign. Sluice valves may also be recommended. If the central air pump is working upon several condensers, any one of them may be isolated by a comparatively small valve placed on the suction pipe connecting with the pump. Possibly this installation is rational under certain circumstances, but more water is used than with a central condenser, as there is no compensation for the variable volumes of evaporated vapors coming from the various appliances into their separate condensers. The care of several condensers necessarily demands more time and attention, especially when economy of water must be taken into consideration.

The question of economy of water is of vastly more importance than many at first sight suppose. It has been previously pointed out that, from the standpoint of expenditure of power, a waste that may be calculated in dollars and cents is involved. Evidently the ideal condition would be to draw the water into the condensers through the action of the vacuum alone and do away with the pumps

entirely. This is within the limits of possibility and has been done, but as a general thing such is not the practice in beet-sugar factories. It may be admitted that the consumption of water for injection depends upon its temperature and the temperature of the waste water from the condenser compared with that of the vapors of evaporation. Under normal circumstances, supposing the temperature of the vapors of evaporation is from 62° to 65° C. with a difference of 10° from the water of condensation, and that the water of injection has a temperature of 10° to 15° C., CLAASSEN says that the consumption of water per kilo of vapor to be condensed is about 15 kilos, or, for 100 kilos of beets, about 150 kilos for the vapors of the multiple effect and 150 to 225 kilos for the vacuum pan. When the vacuum increases the difference between the temperature of the vapor of evaporation and that of the water of injection becomes less, and consequently the volume of water used for injection should correspondingly increase.

The calculated amount of water consumed for injection could only be accurately determined if there were a regular flow of vapors of evaporation as they are liberated from the compartments of the multiple effect. Such regularity can never exist from the vacuum pan. These conditions demand close inspection when each vacuum pan has its own condenser and air pump.

Utilization of waste water.—In beet-sugar factories, with an ample supply of fresh water, the water of condensation may be used in part for the diffusion battery, but its principal usage is for the hydraulic transportation and the washing of beets.

The important and interesting usage to which the water from the condenser is put, how it is received in a special reservoir placed at a certain elevation, and the important services it renders in the beet flumes in carrying the beets to the factory under best possible conditions have been already pointed out. The temperature of this water also prevents all difficulties of frozen beets. An overflow is placed in the water reservoirs, and experience shows that it is desirable to put several tubes on the water piping of beet flumes to carry off the air that the water may have carried with itself. The level of the overflow under consideration should be at least one meter higher than the end of the barometric tube in its water cistern. It is advisable to place above the first overflow a second one which will permit all this water to escape into a river or canal, when the water pipe of the hydraulic carrier is shut.

Cooling of waste water.—In cases where water is lacking it must be cooled to be used over again, which may be accomplished by running it over steps, or into refrigerating and spraying appliances. It may then again render service in the condenser. The conditions of working may demand that these waters be cooled for other reasons. If run directly into adjoining streams there would follow extensive micro-organic developments resulting in objectionable fermentations. Experience shows that 1250 to 1500 liters, or one and a quarter cubic meters to one and a half cubic meters of injecting water, are necessary per minute for the multiple effect and vacuum pan of a 500 ton plant.

The method of water refrigeration depends upon numerous circumstances. The appliances to accomplish the desired results are more or less interesting and as some of them have become standard they deserve special mention. There are certain important points to be considered about cooling. Among these may be mentioned the quantity of water that evaporates and the caloric absorbed from the remainder by doing so. The air which circulates above the liquid becomes saturated with water and is heated at the expense of this water and by radiation. There necessarily follows also a loss of heat by direct transmission through the material of construction of the cooling appliance, though this issue cannot here be discussed in detail.

Upon general principles it may be said that the activity of any waste-water cooling device depends mainly upon the ambient atmosphere, as regards temperature, moisture, etc. The wind is no small item and cannot be overlooked, as when cool it assists very considerably, but when the air is already saturated with moisture the object in view of removing the latent heat of the waste water is not realized.

Cooling in cascades.—In most sugar factories it has been customary for many decades to send the waste or residuary water to be cooled in shallow receptacles where it comes in contact with cold air. The distance over which the water runs varies and, owing to the comparatively low temperature of the ambient atmosphere during the sugar campaign, the cooling offers no difficulty. However, when there is a rise in temperature the surface cooling does not give the expected results. It is proposed then to give greater surface exposure, but this is not practicable, for the change in temperature may be of only very short duration.

The best-known appliances are arranged in cascades made up

of twigs. This mode has been so long in vogue that it may now be considered standard. It consists of a wooden trestle holding a number of fagots, varying with the local conditions (Fig. 71). The warm water is carried through *A* and empties into the upper receiver which distributes it upon the fagots. The downward circulation of the water is comparatively slow, offering to the air considerable cooling surface, and the ultimate fall in temperature is sufficient to allow of its being used in the condensers. Upon reaching *C* the water is pumped through *D* to where it is to be again utilized. There are certain types of closed cascade coolers in which there is a forced circulation of air, either by means of a chimney or ventilator, the size of these appliances depending upon the draught created.

FIG. 71.—Cooling Tower.

The ROHLEDER[1] waste-water cooler consists of a tower in which there are several floors made up of twigs. These, instead of being horizontal, are vertically arranged. The circulating water is distributed on each level through special trough collectors. The tower may be exposed to the ambient temperature or covered, as the case may be. In the latter case a special forced draught is necessary. Water may be thus cooled to 17° C., even in July when exposed to the sun.

RILLIEUX[2] recommended and used a square tower in which were suspended cloths within a few centimeters of each other, and upon these fell the water to be cooled, while a powerful ventilator drove

[1] C., 7, 551, 1899.

[2] HORSIN-DÉON, Traité II, 2, 610, 1901.

the air in the opposite direction. The KOERTING (Fig. 72) mode of cooling does away with the cascade method. In a large circular tank is arranged a ring through which circulates the water to be

FIG. 72.—KOERTING Mode of Cooling.

cooled, and from which it escapes through conical sprinklers arranged at intervals of two meters. Water arrives at a pressure of one atmosphere. In the interior of these conical sprinklers is a spiral (Fig. 73) which forces the water to follow its outer surface, and, when escaping, it forms a deluge of the finest possible spray. Numerous other devices have from time to time been suggested, but the various conditions existing diminish their practical value to a great degree.

FIG. 73.—KOERTING Pulverizator.

Air pumps.—The principal objects of the air pumps are the removal of the non-condensable gases introduced by the juices, the air that enters the appliances through faulty joints, and the gases liberated in the condenser during the cooling of the vapors from the multiple effect. Very little is known as regards the generation of the non-condensable gases formed during evaporation, but they are supposed to be the outcome of non-sugar decomposition. The ammoniacal vapors contain mainly ammonia and carbonic acid, as these are readily absorbed by water, and the same may in a measure be said of carbonic acid. However, when, in the injector, very calcareous waters are used, holding in suspension a certain quantity of carbonic acid, this may be liberated in the condenser and must be drawn off. According to BUNSEN[1] and CARIUS, water dissolves at 15° C. 1.8 per cent of air. The quantity of the air subsequently liberated will depend upon the temperature

[1] Agenda X., 94, 1886.

at which the water leaves the condenser. If it is admitted that 1 per cent is thus set free, then 10 to 14 liters per minute are liberated in a 500 ton plant, which at a vacuo of 72 cm., such as exists in some condensers, represents an expanded volume of 180 to 250 liters. OVERTOP[1] points out that, owing to leaks of all kinds, there enters the apparatus a volume of air representing 10 per cent of the water used during condensation, which, at a 72 cm. vacuum would mean from 1800 to 2500 liters.

Various types of air pumps.—Air pumps, such as are mentioned in the foregoing, may be for dry or moist air, and they may have flap valves, slide valves, or ordinary valves. It has frequently been suggested that injectors instead of air pumps be used, and DEHNE attempted to use a KOERTING steam injector instead of the pumps, but it was shown that the vacuum obtained was not sufficient. The results in this direction obtained by BORN[2] were more certain, but could not always be depended upon. MAXWELL[3] proposed that rotary pumps be employed.

Moist-air pumps.—When barometric condensers are not used, the moist-air pump plays an important rôle. As has been previously pointed out, the water and non-condensed gases must be removed from the condenser by their use. Moist-air pumps have oscillating metal or rubber flap valves. In Fig. 74 is shown one of these arrangements constructed by CAIL. When the piston moves from left to right, the pump draws from the condenser the water and non-condensable gas through the entrance port, *E*, and these raise the valve in front of *C* and enter the cylinder *A*, while on the other side of the piston the water and the gases are forced up through *D*. The top valve opens into the tank, *F*, which has a suitable overflow—not shown in the illustration—and a pipe of sufficient diameter to allow the gases to escape. The weight of the valves is an important point to be considered, or if too heavy they will necessarily considerably reduce the efficiency of the pump, and yet they must be very solidly constructed, so as to resist the shocks sustained from falling upon their seats.

In Fig. 75 is shown a German type of a rubber flap valve, the arrangement of which is very much the same as the metal flap-valve pump, just described. The piston *a* works from left to right, drawing the water and gases in through *b*; the flap valve, *c'*, then

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[1] Archief, 9, 129, 1901. [2] Z., 23, 1022, 1873.
[3] D. Z. I., 12, 1194, 1887.

opens and on the other side of the case d is forced open. When the piston is working from right to left it is the valves c and d' that are open, while c' and d remain closed. The piston rod and stuffing-box arrangement are surrounded by a basin, g, filled with water, which arrangement forms a perfect air joint.

The STORK (Fig. 76) moist-air pump offers several interesting characteristics. The plunging piston, A, consists of a bronze

FIG. 74.—Section Moist-air Pump.

cylinder with conical ends, adjusting exactly in the end covers of the pump, so as to do away with the dead spaces as far as possible. Its working is easy and noiseless. The water and gas enter at E and pass into B or B', depending upon the position of A, and are forced out either through the valves, C or C', which have a very considerable section, as shown in the plan and section drawing (Figs. 77 and 78). It is claimed that the arrangement permits great rapidity in the pump's working, which in special cases may be of great service. The valves in question rest upon an iron grating. There are ten clusters and the opening is comparatively slight.

Moist-air pumps work at a velocity corresponding to 30 to 50 revolutions per minute. As a general rule, it is a mistake to ex-

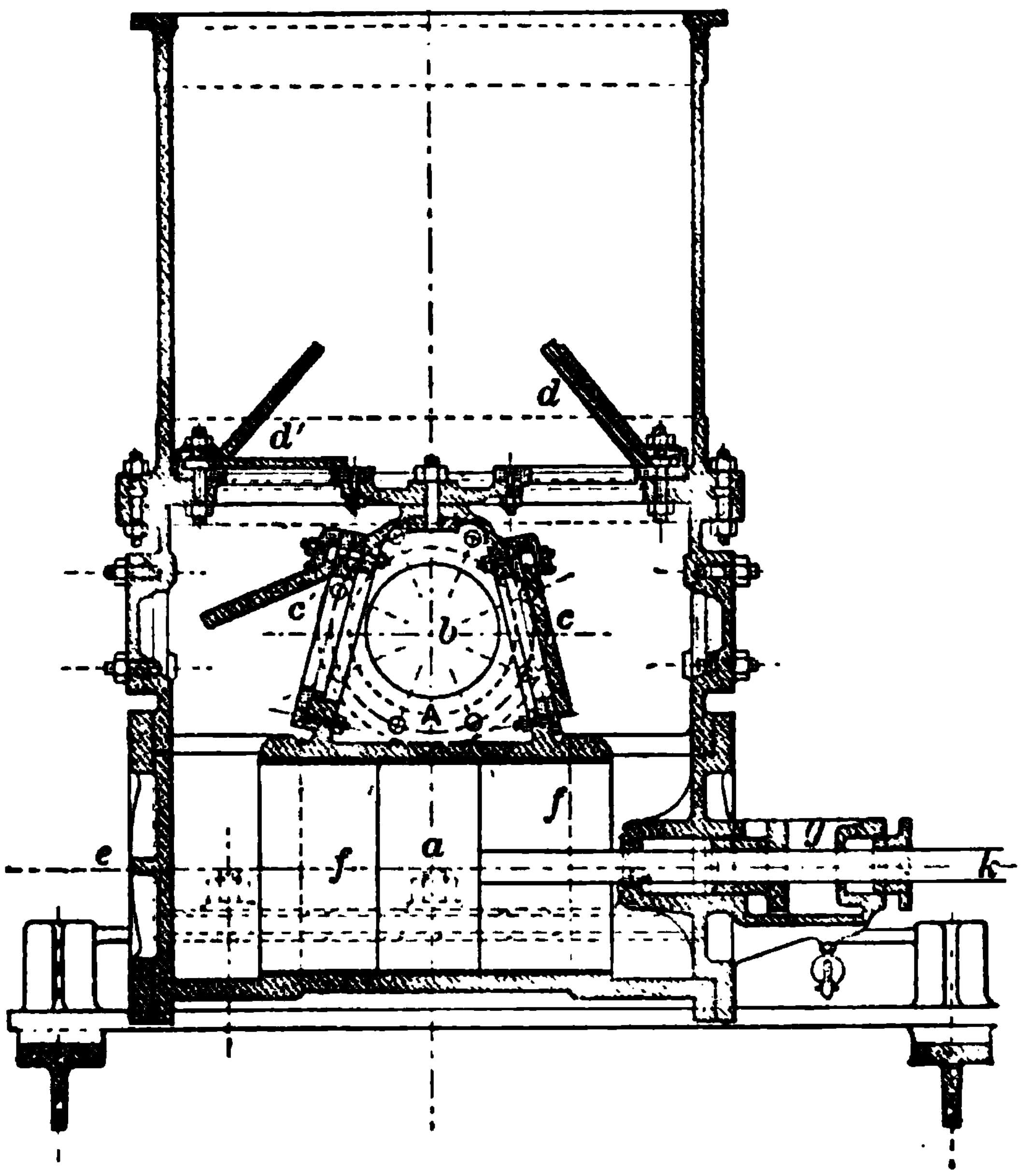

FIG. 75.—German Moist-air Pump.

ceed that velocity, as the valves would soon suffer from the repeated shocks. When a moist-air pump works in combination with a counter-current condenser, the vacuum may be regulated

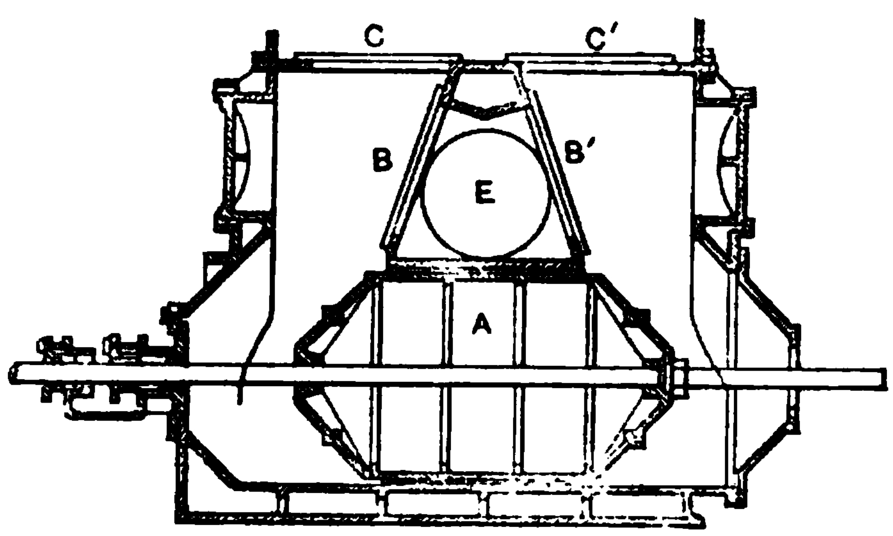

FIG. 76.—STORK Moist-air Pump.

by opening a cock making a communication between the top of the condenser and the air pump.

In theory there are no dead spaces in a moist-air pump, as they are filled with water that is non-compressible; but the fact

is, such water always contains air bubbles in suspension. During the back stroke, these bubbles assume a volume that is directly proportional to the pressure, and the piston must reach a certain position before they are expanded sufficiently to have a pressure less than the water and gases on the other side of the suction flap

FIG. 77.—Top View of Valve Arrangement of STORK Moist-air Pump.

valves, so that these may open; hence the desirability of having easily working valves.

MARCHAND proposed that the efficiency of a moist-air pump be increased by placing a centrifugal pump at the bottom of the condensers, with a view to remove nearly all the injected water. The air pump under these circumstances would draw off only the non-condensable gases. It is important, when using the centrifugal for such purposes, to have the centre or suction portion placed

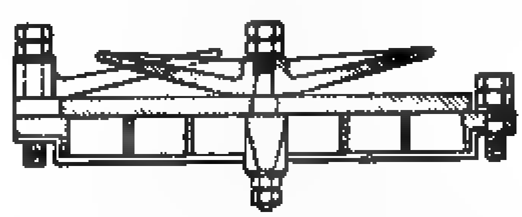

FIG. 78.—Section of Same Valve.

directly in front of the pipe connecting with the condenser.[1] LE DOCTE[2] used for the same purpose a centrifugal pump, whose efficiency was automatically regulated by the level of the water to be extracted from the condenser. The principal objectionable features of moist-air pumps are, that their efficiency is restricted to very narrow limits, and that they should not be used with hard water, as there would always be considerable calcic deposits,

[1] S. I., 51, 165, 1898. [2] S. I., 51, 199, 1898.

owing to the comparatively high temperature at which the pump is working.

Dry-air pumps.—As a general thing, dry-air pumps are mainly used in combination with counter-current injectors. The non-condensable gases only are drawn off. These appliances are very differently arranged from the moist-air pump, and their construction has undergone many alterations from the original design. Among the first devices were such as had metallic flap valves, which through suction were given an automatic movement, very like that used in air compressors; but this arrangement, owing to the low density of the gases to be drawn off, resulted in a vibration of the valves which were frequently fractured. It is claimed that these valves do not rest as firmly upon their seats as they should. In France they have been to a certain extent abandoned, while in Germany their adoption gives excellent results. The method most in vogue is the use of a distributing slide valve, very like those used in the blowing engines for carbonic acid. In order to obtain with these pumps a maximum efficiency it was proposed by various combinations to do away entirely with the dead spaces, which may in certain cases be of considerable importance, the average being about 4 per cent of the cylinder's capacity.

In what follows there will be shown the various devices having the object of overcoming these difficulties by doing away with all packing of the piston and preventing it from touching the sides of the cylinder. The tightness is obtained by tracing grooves on the generatrix of the piston, which arrangement is very like that used in the pneumatic laboratory pump. Joule [1] was the first to practically adapt the groove principle to the cylindrical surface of the piston of an air compressor. Wellner [2] in 1879 used pistons with annular grooves to increase the efficiency of the air pump. In the free space, between the piston and the cylinder, an exchange of air takes place between the sides where the air was forced out and where it is drawn in. It is claimed that the arrangement does away in an important measure with the inconvenience of dead spaces.

Description of some improved types of dry-air pumps. The best of them are made after the model of Bürckhardt and Weiss (Fig. 79), a transverse section of which is shown herewith. An examination of the sketch shows how the slide valve T is worked.

[1] Jahrb., 5, 120, 1866. [2] D. Z. I., 11, 730, 1886.

The inlet A is alternately put in communication with both sides of the piston, P, by the distributing ports, C and C'. The air is forced out during the back stroke through D and D', openings in the slide valve. These are covered by a sliding plate, E, held in position by a spring pressure, which moves with the main slide valve, T, and rises only when the back stroke pressure is equal to that of the exterior atmosphere. This permits the compressed gases to escape through the piping, R. In the drawing it is supposed that the piston, P, is at the end of its stroke and will soon resume its

FIG. 79.—Section of BÜRCKHARDT and WEISS Dry-air Pump.

movement in the direction of the arrow, f. At that moment the gases behind the piston are compressed into the dead spaces and are at the atmospheric pressure, while those in front of the piston have only a very slight tension corresponding to the vacuum in the condenser from which they were drawn. The slide valve, T, has a straight motion in the direction of f' and at the instant under consideration is in an average position.

The width between the nearest borders of the openings D and D' is greater than the greatest distance between the corresponding parts of the ports C and C', so as to retard the admission and the compression of the gases. The two openings, FF', connect through a horizontal pipe which puts in communication the front

and back of the piston, P, through the ports, C and C'. It is self-evident that the gases compressed between P and AR will pass through C', $F'F$, and C, and will expand on the other side of the piston. As soon as the piston has travelled a space equal to the width of the openings of expansion this communication is interrupted and at the same moment the space C' being in communication with A the suction commences, because the compressed gases have been previously expanded to the existing tension of the condenser. This suction ends shortly before the piston reaches the dead point. During this time the gases are forced in front of the piston through the passages C and D. When they have attained the atmospheric pressure the beating valve or plate E is raised, the shock of which is lessened by the spring G, and they escape through the piping R. When the piston, P, reaches the end of its stroke the slide valve, T, has returned to the same position as it previously occupied, the expansion of the compressed gases in the dead spaces in front is operated as in the foregoing, but in the reverse direction, thus permitting an immediate suction. At each passage of the dead point the same phenomenon, consisting in momentarily placing in communication both sides of the piston, is repeated. The air piston consequently commences its suction almost from the start of its stroke in front or back, and the efficiency of the pump is consequently very great, as compared with the flap-valve model.

The WEGELIN and HUEBNER slide-valve arrangement for dry-air pumps is shown in Fig. 80. The principal distribution is through the slide valve, T, and the annulling of dead spaces is accomplished by the equalizing valve, E, which has the function of placing the two sides of the piston, P, in communication when it passes over the dead point. The drawing supposes that the piston is at the end of a stroke just before it travels in the reverse direction, f, and the principal slide valve, T, moving in the direction, f', is supposed to be at its middle position, which shows some delay both for suction and forcing. The equalizing valve, E, is moving in the direction f''; it will open the passage, C', and place it in communication with C, thus permitting the expansion of the gas in front of the piston. The communication is interrupted before the principal slide valve, T, has allowed the beginning of the suction through the passages, $C'A$, which suction ceases before the piston reaches the end of its stroke in the direction, f. During this period the air is being forced through C and D, the valve, S, has opened, permitting the compressed gases to make their escape and

subsequently to flow through the pipe, *R*. As soon as the piston reaches the dead point at the other end the principal slide valve *T* returns to its middle position and the equalizing valve, *E*, again establishes an equilibrium of pressure upon both sides of the piston, *P*. This operation continues for every stroke of the piston and overcomes the dead spaces.

An excellent type of single slide valve with the same object is that adopted by the St. Quentin Construction Co. The distribution

FIG. 80.—Section of WEGELIN and HUEBNER Dry-air Pump.

is accomplished through the slide valve, *T* (Fig. 81), which, through its movement, places both sides of the air piston alternately in communication with the suction pipe, *A*, and with the force pipe, *R*, through the openings *D* and *D'* and several valves *SS* placed on top of *T*. The drawing supposes the air piston at a dead point at the moment when it is about to move in the direction *f*. *T* is supposed to be in its middle position and moves in the direction *f'*. The doing away with the dead spaces is accomplished through the supplementary passage, *EE'*, which places both sides of the piston in communication. This condition is interrupted (as shown in the drawing) before the suction or forcing commences, and the same operation is repeated at the other end of the stroke. The object in view, as in the appliances previously described, is to permit the expansion of the compressed gases and to do away with the dead

spaces on both sides of the piston, this necessarily being followed by a greater efficiency of the dry-air pump.

The dry-air pumps are since many years very much in vogue, as their efficiency reaches 90 or 95 per cent and even more in pumps of considerable size.

FIG. 81.—St. Quentin Slide-valve Dry-air Pump.

Dry-air pumps with flap valves.—Of late years dry-air pumps have been constructed with flap valves, which are very sensitive and will open or close under the slightest difference of pressure. These valves are placed upon the head of the cylinder. The dead spaces in these pumps are very small. In the dry-air pumps under consideration there always remains a space of some few millimeters between the heads of the cylinder and the piston after each stroke. In case the condensers are badly combined and water finds its way into the cylinder accidents might occur, but they are very rare. Special precautionary measures may be taken. It is frequently pointed out that one of the objectionable features of the flap-valve dry-air pump is the repeated shocks caused by the valves, particularly when of abnormal size. Springs are used to keep the valves well pressed upon their seats and there are numerous combinations, such as the so-called cataract valve, balanced valve, etc. In some of the existing dry-air pumps of this type 300 strokes of the piston per minute are attained. The weak springs connected with the valves during their working permit the escape of the last portions

of air forced out by the piston. Their efficiency[1] is extremely high, frequently reaching 97 to 98 per cent. The BLANCKE air pump is a good type of the cataract-valve mode. In Fig. 82 are shown the left and right portions respectively of the pump during the period of suction and forcing.

The suction valve consists of a series of sleeves with rectangular openings, *Z* and *X*, a ring and flap valve, *U*, which telescope one into the other, leaving between them the annular spaces, *V* and *U*. A spring, *N*, helps the valve to close under the slightest difference of pressure. While the non-condensed gases are aspirated on that side the gases on the other side of the piston are being com-

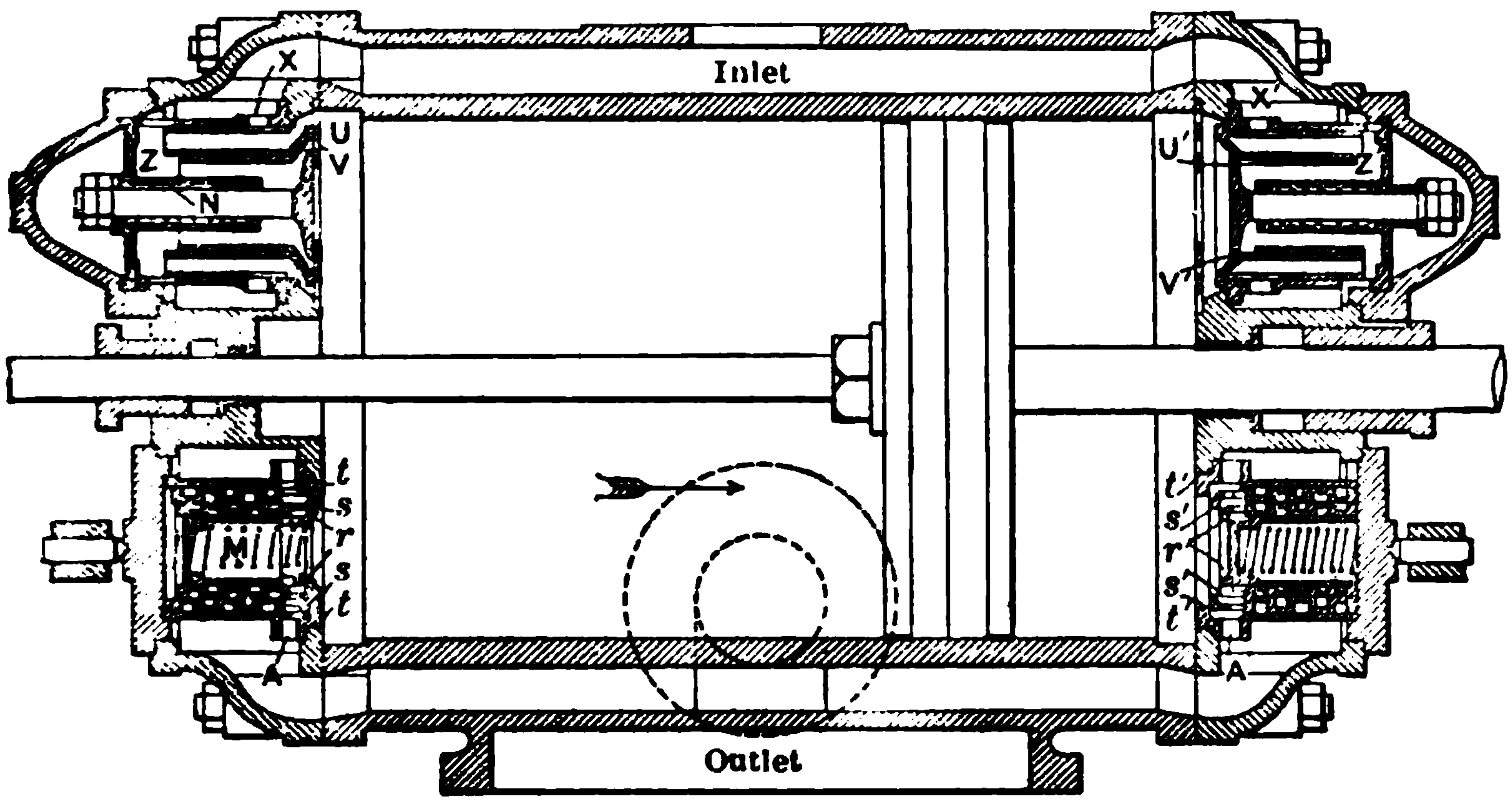

FIG. 82.—BLANCKE Valve Dry-air Pump.

pressed and force all the sleeves of the upper valve in the right corner against one another by doing away with the annular spaces, *V'* and *U'*, covering also the openings, *X'* and *Z'*. On this same side the cylindrical sleeves of the force valve are opened to allow the air to escape by *s'*, *r'*, and *t'*. On the other side the sleeves are all pressed one upon the other by the spring *M*, thus preventing any passage through the seats of these valves. It is interesting to note that in this arrangement the exit valves are at the bottom and the entrance valves on top of the cylinder, in order to facilitate the evacuation of the water.

In the HAHN[2] pump (Fig. 83) the dead spaces are entirely eliminated. The slide valve, *g*, has the shape of a ring of the same inside diameter as the cylinder, *a*, of the pump. When it changes

[1] D. Z. I., 11, 1022, 1886. [2] D. Z. I., 27, 1982, 1902.

its position it opens an annular space, *n*, through which enters the non-condensed gases. There can be no dead spaces, for the reason that the seat of the slide valve is upon the periphery of the cylinder itself. The back part, *l*, of the cylinder has a cover which acts as a valve and is pressed upon the outer borders of *l* by means of a spring. When the piston reaches the end of its stroke it lifts this plate allowing the gases to escape through *h* and *k*. As the cover adjusts itself exactly to the cylinder at the end of the stroke dead spaces cannot exist. There is no shock and consequently very little wear and tear. It is pointed out that this pump has considerable efficiency and may attain a vacuo of 75 cm. of mercury.

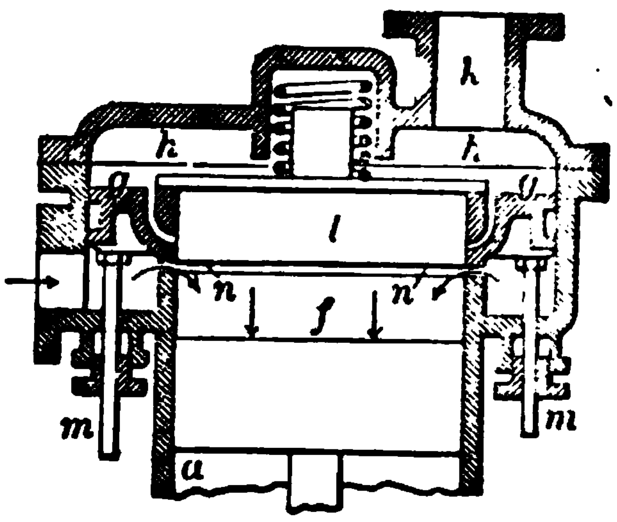

FIG. 83.—HAHN Air Pump.

Size of the air pump.—Authorities do not agree as regards the importance of air pumps, and, when visiting factories, one is struck with the great variance in the pumping capacity of these machines. Their working depends upon the condenser. In modern modes of sugar extraction there is a constant tendency to increase the size of the plant, and these changes are frequently not allowed for in the air pump. Suddenly it is realized that the vacuum is insufficient in the multiple effect and pan. Let the air pump correspond in size to any extreme case that it may have to meet. EHRHARDT[1] noticed one case in which the vacuum in the air pump was 748 mm. of mercury or 98.4 per cent, notwithstanding the fact that in the condenser the vacuo was 720 mm., and in the syrup compartment of the multiple effect 671 mm. pressure. The conclusion to be drawn is that the sections of the several pipes were entirely too small.

According to BOUCHON[2] the dry-air pumps of the German and Austrian model will develop 250 and sometimes 300 liters per kilo of steam to be condensed, while in the Belgian pumps this is less than 200 liters. In order to increase the efficiency of a dry-air pump the exterior surface of the cylinder is frequently cooled, as the volume of gas drawn into the cylinder decreases in direct ratio to this temperature. Another method consists of injecting into the cylinder small quantities of water. Certain pre-

[1] D. Z. I., **15**, 1402, 1890. [2] Bull. Synd., **17**, 592, 1894.

cautionary measures must be adopted, because, as has been explained, there would be danger of knocking out the head of the cylinder.

Air-pump transmission.—The motion is transmitted to air pumps either by suitable belting or special engines. According to GREINER[1] when belts are used the pumping capacity should not be calculated upon averages, but upon the maximum work to be accomplished. Experience shows that belt transmission is too much dependent upon other shafting and if an accident occurs the whole evaporating and boiling plant comes also to a standstill, so it is better to have a separate engine.

MAGUIN'S (Fig. 84) arrangement is of special interest, as it allows of either belt or machine transmission. In this case the steam engine is placed behind the air pump, and the latter between

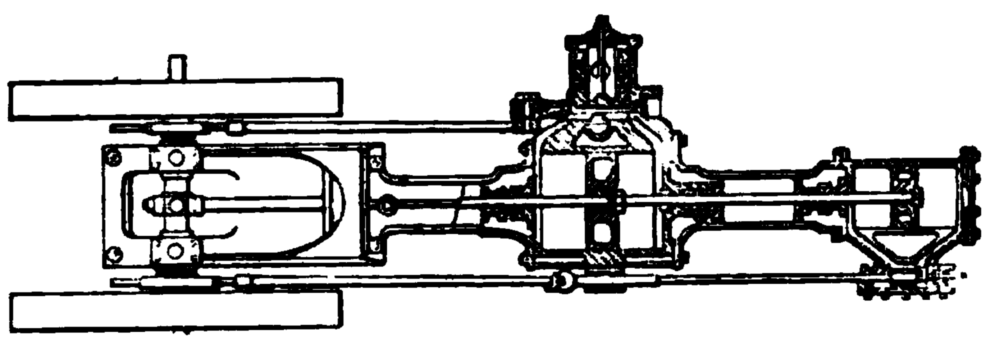

FIG. 84.—MAGUIN Combination.

the engine and fly wheel. If the belting is faulty the gearing may be made with the engine. It is a great mistake not to use a heavy fly wheel in connection with the engine, as in the pumping cylinder the maximum work is to be accomplished just at the moment the steam is expended in the engine cylinder and can exert the least power, and as a result the machine slacks upon reaching the dead points. A mode sometimes adopted to overcome the dead points consists in using for the pump suitable cranks keyed to the fly wheels of the engine at an angle of 90° as compared with the cranks of the engine. STEFFENS[2] tried to overcome the difficulty by other means, such as reducing the energy consumed by the air pumps. The air is forced into a receptacle in which there is a slight vacuum. It is claimed that, under these circumstances, a high vacuo may be reached, even when there are dead spaces in the cylinder of the pump. It is to be noted that this mode demands the use of a second air pump.

Perturbations in the working of air pumps.—When not working under normal conditions the vacuo in the air pump is not up to

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[1] D. Z. I., 6, 1225, 1881.   [2] D. Z. I., 19, 113, 194.

the desired standard. The working parts of the pumps should be in perfect condition, that is, the port passages and the seats and laps of the valves should be free from all foreign substances. All exterior air should be kept from the cylinder by suitable packings, stuffing boxes, etc. It may be admitted that flap-valve air pumps are very much less likely to be broken by the introduction of water into the cylinder than the other modes.

Diagrams of the working of the machine should be taken. They allow to ascertain at once whether the exit air ports are of sufficient diameter, if the valves are too light or too heavy, etc. The diagrams give information respecting the leaks in the cylinder. If, for one reason or another, the moist-air pump gets out of order for any length of time there is a general stoppage of the factory. Sometimes valve-water pumps have proved to be of great assistance in such emergencies. While a vacuum will thus be produced in the multiple effect and pan, it will hardly be sufficient to accomplish the evaporating work for any length of time. The carbonic-acid pump may also come to the rescue in helping to complete the work in progress until the air pump is ready to resume operation. An extra air pump and condenser should always be provided so as to be prepared for such emergencies.

CHAPTER VI.

MULTIPLE REHEATING.

General considerations.—In all beet-sugar factories the demand for heating is not confined to one station, but extends to every phase of the manufacturing process. Graining in pan must be accomplished under satisfactory economical conditions, juices from the battery must be reheated, etc. It would not be economical to use the exhaust steam directly from the engines for this purpose. There are considerable advantages in taking a portion of the liberated vapor from the first compartment of a multiple effect. The exhaust steam, passing into the heating chamber of the said compartment, will bring about the evaporation of a part of the water contained in the juices, and this, if sent to pan, answers for the purpose of graining. The arrangement in reality is a double effect. Authorities do not agree as to who was the originator of this idea. According to PÉCLET[1] it is PELLETAN to whom must be given the credit of having been the first to use the vapors from evaporation for heating. He used an injector in order to submit the expanded vapors to a preliminary pressure before reaching the injector, and they were forced into coils used for reheating syrups before they entered the vacuum pan.

On the other hand, in the American patents RILLIEUX mentioned in 1846 the use of the vapors from the first compartment of a triple effect for graining in pan, and described in great detail the mode as it was practiced. Since then it has been greatly improved. No stress need be laid on the assertions of SIMON[2] who claims that SANTERRE should have the credit of the innovation in its new form; and, again, LEXA[3] asserts that FISHER was the principal leader in this mode of vapor utilization (?).

[1] PÉCLET, Traité de la Chaleur II, 2, 80, 1843. [2] S. I., 17, 326, 1881.
[3] B. Z., 8, 206, 1884.

This multiple heating is accomplished by a great variety of methods. Before describing them it is interesting to show just how they actually accomplish a caloric economy in the sugar manufacture. In the diagrams herewith, in which the conditions are only roughly represented, one may see how this steam economy is realized. It is supposed that each compartment liberates exactly the quantity of caloric that it receives, and that one kilo of vapor will evaporate three liters of water in a triple effect. Suppose, also, that 300 liters of water are to be evaporated and the reheaters are to receive a total of 50 kilos of vapor. In the first case the triple effect and the reheaters are supplied with live steam or with exhaust steam.

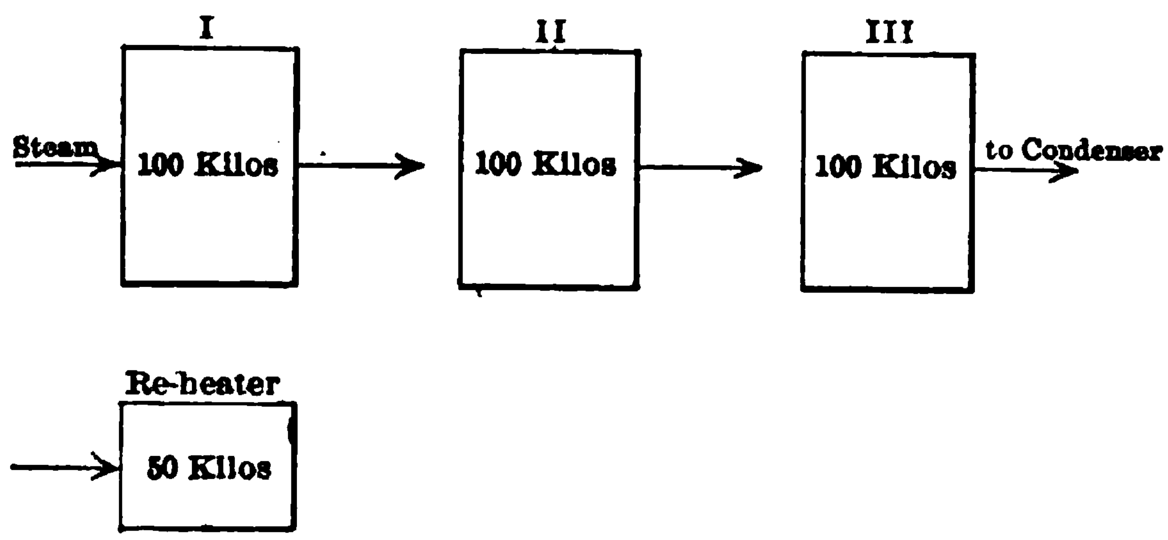

FIG. 85.—Economy of Multiple Reheating—First Case.

First Case (Fig. 85).—The triple effect must evaporate in each of its compartments $\frac{300}{3}=100$ kilos of water, and must consequently receive 100 kilos of live steam to which must be added the 50 kilos consumed by the reheater—total consumption, 150 kilos.

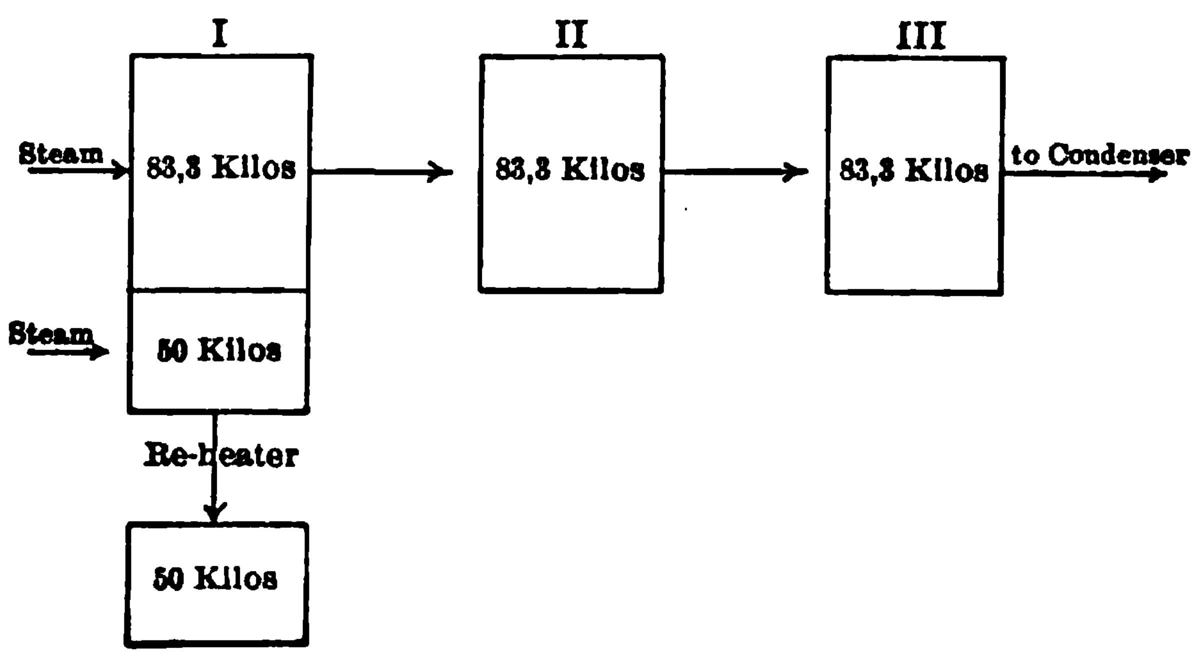

FIG. 86.—Economy of Multiple Reheating—Second Case.

Second Case (Fig. 86).—The triple effect in the second case is heated with live steam and the reheaters by the vapors from

the first compartment of the triple effect; consequently, 50 kilos of vapor will be removed from that compartment, and it becomes necessary under these circumstances to send to it 50 kilos of steam. There will remain $300-50=250$ kilos of water to be evaporated in the triple effect, which means $\frac{250}{3}=83.3$ kilos per compartment. For this purpose the apparatus will consume about 83.3 kilos of live steam or a total of $83.3+50=133.3$ kilos, the economy being consequently $\frac{(150-133.3)100}{150}=11.1$ per cent.

Third Case (Fig. 87).—The triple effect in the third case is heated with live steam and the reheating is accomplished with vapors from the second compartment.

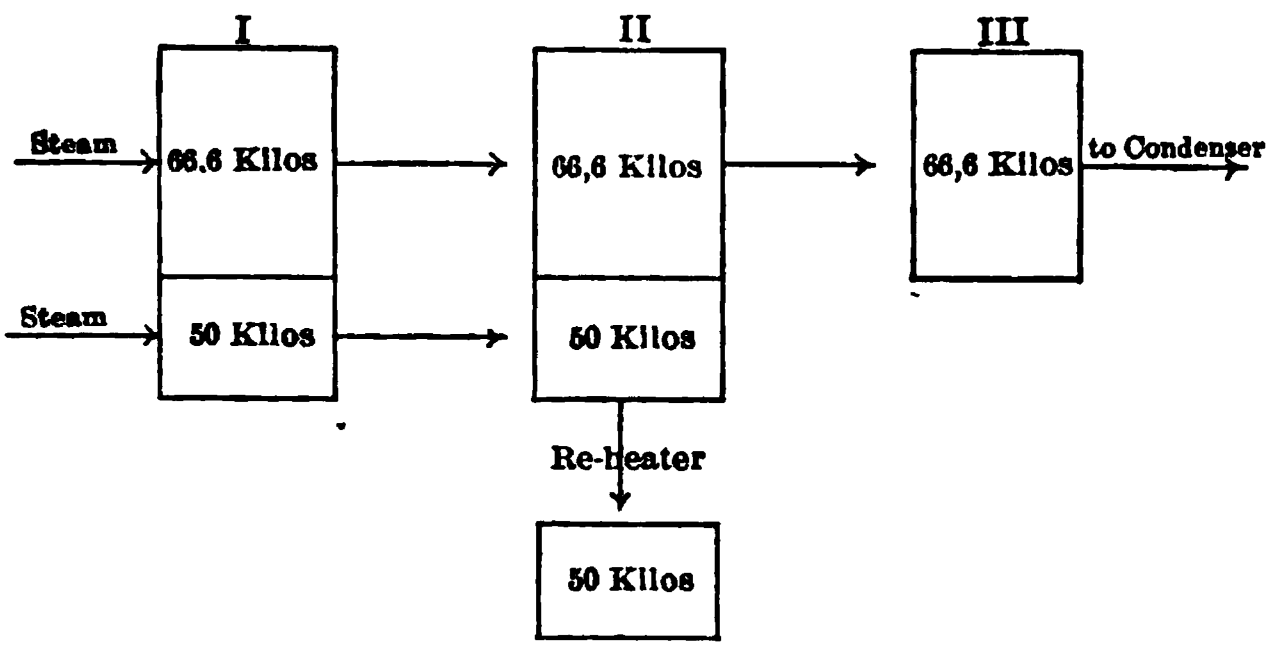

FIG. 87.—Economy of Multiple Reheating—Third Case.

The 50 kilos of steam consumed in the reheaters corresponds to 50 kilos of water evaporated in each of the compartments, *I* and *II*, and also to the consumption of 50 kilos of live steam in the first compartment. Under these conditions 100 kilos of water are evaporated. There still remains 200 kilos, or $\frac{200}{3}=66.6$ kilos for each compartment, or 66.6 kilos of live steam used at the start, to which must also be added the 50 kilos previously mentioned. This gives a total of $66.6+50=116.6$ kilos, and the economy realized as compared with the first case is $\frac{(150-116.6)100}{150}$ $=22.2$ per cent.

Fourth Case (Fig. 88).—The triple effect in the fourth case is heated with live steam and the reheater with vapors from the third compartment.

All the juice is evaporated by the triple-effect mode and demands 100 kilos of live steam. The reheater consumes a portion of the lost vapor and demands no special supply. The economy consequently is $\frac{(150-100)100}{150}=33.3$ per cent.

The practical value of an installation, calculated upon the basis just mentioned, depends upon the consumption of steam for heating purposes in the sugar plant. Experience and calculation show that the more steam taken from the evaporating apparatus for heating and graining the better the steam economy, avoiding as far as possible the use of live or exhaust steam for these purposes. If this principle is well carried out CLAASSEN says that better results can be obtained with a quadruple effect than with a quintuple or sextuple effect, with a poor application

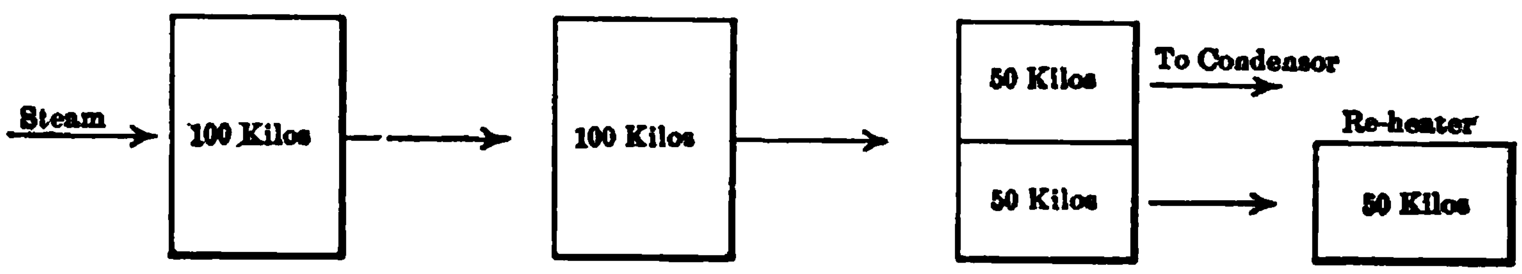

FIG. 88.—Economy of Multiple Reheating—Fourth Case.

of this method, and that even a triple effect may be more advantageous, when fuel can be had for a reasonable price. In well-calculated beet-sugar factories with simple evaporating appliances the total consumption of steam estimated upon a basis of 100 kilos of beets sliced is about 60 kilos, including losses due to cooling. No well-organized beet-sugar factory should consume more than 70 to 75 kilos of steam, and, all this steam should be sent in the condition of live or exhaust steam to the first compartment of the multiple effect, or to the fore-evaporator, unless live steam is injected into the diffusion battery.

Without doubt the multiple reheating very considerably increases the evaporating efficiency of a multiple effect. When, for example, the vapors are taken from the first compartment of an evaporator an additional amount of vapor may be obtained from it without increasing the area of heating surface, it being sufficient merely to increase by a few degrees the fall of temperature between the vapor used for heating and the boiling-point temperature. This offers no difficulty, as the pressure of the steam in the exhaust-steam collector may be regulated at will, and, furthermore, the fall of temperature in the first com-

partment is comparatively small. If we suppose, for example, a quadruple effect with a fall of temperature of 8° C. between the vapor used for heating and the boiling juice in the first compartment, an increase in the fall of 4° C. will augment the efficiency of the first compartment of the multiple effect by 50 per cent, and the total efficiency will be increased 12.5 per cent. In a triple effect, if the fall of temperature in the first compartment instead of being 12° C. becomes 16° C. the efficiency of the first compartment is increased 33.3 per cent, and the increase for the entire apparatus, taking all the compartments collectively, is 11.1 per cent. It must be noted, however, that if the economy of the evaporating appliances consists in taking vapors from compartments further and further from the first compartment the increase of efficiency is finally reduced to zero.

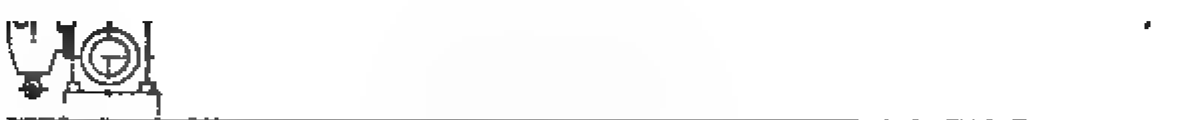

FIG. 89.—LEXA and RILLIEUX Method.

The Lexa-Rillieux method.—It is possible by this combination, as with any other, to work by triple, quadruple, or other modes, but the quadruple method is the one generally used. When working by triple effect it is commonly recommended to draw the vapors only from the first compartment, while in all other cases they may be drawn from the first and second. When working by quintuple effect the vapors are drawn off even from the third compartment.

In Fig. 89 is shown a quadruple effect with multiple mode of reheating. The evaporating apparatus for beet juices consists of four compartments, *A*, *B*, *C*, and *D*. The first compartment, *A*, furnishes the vapor to *B* and to several reheaters, *E*,

F, and *G*, through which circulate juices or syrup on the way to their respective stations where they are to be heated from 90° to 100° C. This first compartment is heated with the exhaust steam from the collector, *R*, in communication with the various motors of the sugar factory. Live steam may be introduced through *V*. This must, in case the engines do not yield an excessive volume of exhaust steam, be employed on account of the exceptional evaporation that this compartment is called upon to furnish. The second compartment, *B*, is heated, as just explained, by means of vapors from *A*, and furnishes the requisite heating for *C*, and, through the medium of *H*, for one or more reheaters that need temperatures from 80° to 90° C.

The third compartment, *C*, furnishes to *D*, in which the concentration terminates, an amount of vapor and non-condensable gases subsequently abandoned in the condensing injector, *O*, from which they are removed by the air pump, *P*. By the combination of a quadruple effect it is evident that the heat lost through condensation is considerably reduced, and, furthermore, as from the first compartment, *A*, there has been taken regularly a portion of the vapor for reheating, it follows that the evaporation, instead of being equally distributed between the evaporating compartments, decreases from the first to the last. The latter, instead of yielding up to the injecting condenser the theoretical amount of vapor, equal to 25 per cent of the water evaporated, will allow a total amount of heat to escape inversely proportionate to the previous utilization of the vapor taken from *A* for heating purposes. This economy of fuel will reach its maximum when all the heating of the sugar plant is done with the evaporated vapors from the multiple effect. Evidently a portion of the escaping caloric from *D* could be properly utilized for various reheatings.

This mode permits of a vast number of combinations, among which may be mentioned that shown in Fig. 90. According to Rillieux a factory working with a plain triple effect would gain some advantages in transforming it into a double effect with multiple reheating. The exhaust steam from the engines enters first in *A*, and the resulting vapors run into *B* and *C*, which are combined so as to form one double compartment. To establish an equilibrium between the heating surfaces of *B*, *C*, and *A*, certain precautionary measures must be taken. How to increase the efficiency of the first compartment by increasing the fall of pressure in the apparatus has already been explained. But in

the RILLIEUX apparatus under consideration other methods are adopted on account of the engines from which the exhaust steam is drawn. Live steam may be introduced into a coil placed at

FIG. 90.—Variation of RILLIEUX'S Combination.

the bottom of one of the evaporating compartments (Fig. 91), but in this case another mode is used.

This may also be accomplished in an apparatus called a circulator, which communicates with the compartment above and underneath the tubular cluster (Fig. 92). The upper communication permits an escape for the vapors liberated from the juice by heating

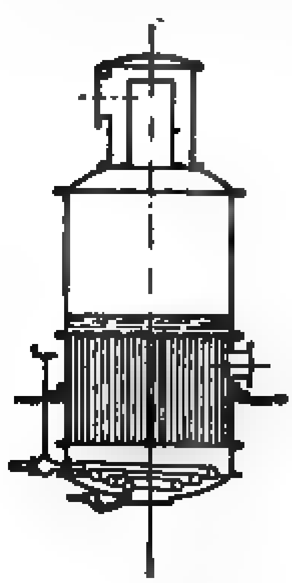

FIG. 91.—Live Steam Heating Heavy Coil.

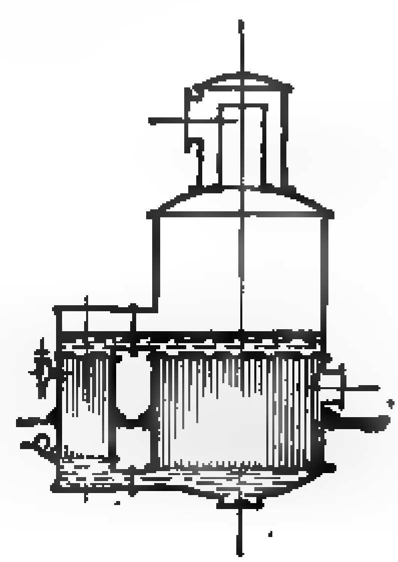

FIG. 92.—HECKMANN'S Circulator.

with live steam in the circulator. This combination effects a methodical heating, which certainly increases the evaporating efficiency of the compartment. The circulator may assume the shape of one of the compartments of the multiple effect, independent of A, and serve for several heating purposes.

In the combination represented by Fig. 90 there is formed a double effect with an increased evaporating efficiency. The first

compartment has its circulator, *V*, and the second consists of joint compartments, *B* and *C*. The vapors from *B* and *C* escape through the common pipe, *K*, and are used in the calorizators, *M*, of the diffusion battery, in the carbonatating tanks, *H*, and the vacuum pan, *L*.

As the diffusion battery is generally placed at some distance from the multiple effect calorizators with heating surfaces of exceptional size are necessary. In the utilization in the vacuum pan of the vapors from the first and second compartments of a multiple effect the coils of the pan must be of an exceptional size, owing to the fact that the vapors in question are at a low pressure. The graining with this vapor can be done under favorable circumstances in tubular and horizontal appliances of the JELINEK, LEXA-HEROLD, or similar types. These combinations are very numerous, and the requisites vary with each factory according to the special conditions there existing.

The experts discussing the advantages and disadvantages of the LEXA-RILLIEUX methods point out that a considerable counter pressure in the engines is involved; but this argument holds good only in cases where the heating surface is not sufficient for the evaporation and the different heating appliances. RASSMUS [1] has noticed that the pressure of the exhaust steam in German factories, using evaporation and multiple reheating of juices in the triple and quadruple effects, was, for four consecutive weeks, about as follows:

AVERAGE PRESSURE OF EXHAUST STEAM IN FACTORIES USING EVAPORATION AND MULTIPLE REHEATING (RASSMUS).

Triple effects.				Quadruple effects.			
1st week.	2d week.	3d week.	4th week.	1st week.	2d week.	3d week.	4th week.
Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.
0.18	0.21	0.16	0.2	0.4	0.5	0.5	0.4
0.2	0.1	0.1	0.1	0.3	0.25	0.25	0.4
0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5
0.5	0.5	0.5	0.5	0.35	0.35	0.35	0.5
0.2	0	0.1	0.1				
0.5	0.4	0.3	0.3				
0.4	0.5	0.4	0.4				

Argue as one may it cannot be denied that the LEXA-RILLIEUX combination demands exceptionally large heating surfaces at all

[1] D. Z. I., 11, 1902, 1886.

the stages of sugar extraction. The question may be asked, From which compartment, the first or the second, should the vapors be taken? This depends upon the size and the power of transmission of the heating surfaces of the evaporator, the vacuum pan and reheaters, and the temperature at which the reheating and graining should be effected. According to the temperatures given by Horsin-Déon for the quintuple effect, nearly all the heating may be accomplished with the vapor from the second and third compartments, which means the use of a triple and quadruple utilization of heat. One may reheat cooled diffusion juices with vapors liberated from the concentrated juice in the last compartment, as these vapors have a temperature of 60° to 65° C., while the juice is not hotter than 25° to 35° C. This mode of reheating is advantageous in that it is accomplished without expense by using vapors which would otherwise have been lost.

As it is impossible to utilize all the lost vapors, either from the multiple effect or the pan, it is certainly desirable to save some of the heat lost through condensation by reducing in both appliances the evaporating work to be accomplished. In the vacuum pan, which is a simple-effect apparatus, this economy may be realized only by effecting the graining with very thick syrup, and as to the multiple effect the result may be obtained by the use of special methods tending to diminish the work of evaporation in the last compartment, and at the same time leaving the final syrup as dense as possible.

All the other juices need for their reheating vapors a temperature of 90° to 100° C. and frequently higher. These must be taken from the first two compartments of a quadruple effect, from the first only in the case of a triple effect, or in the case of a fore-evaporator the vapor may be taken from it and the first compartment.

The Pauly-Greiner method.—It was pointed out that the method of multiple heating described in the foregoing had one very defective feature, which was the need of exceptionally large heating surfaces, especially for graining in pan or the increasing of the pressure in the exhaust-steam collector. This difficulty was overcome in a great measure by Pauly. The apparatus recommended by him is called in German *Vorkocher* or *Saftkocher;* in English the term "fore-evaporator" has been adopted to describe it.

The fore-evaporator is an apparatus entirely outside of the multiple effect, and is heated with steam taken directly from the high-pressure boilers. It should be used in beet-sugar factories in

wh ch the exhaust steam from the various machines is not sufficient for the evaporation of the juice, and direct steam from the boilers must be used; also when one wishes to obtain vapors for the vacuum pan and the reheating at the highest possible pressure, such as the multiple effect can never furnish. In the fore-evaporator the pressure of the vapors liberated from the juice during boiling may be made to rise to three-fourths of an atmosphere and even to one atmosphere. Under these circumstances the temperature of the vapors used for boiling may be forced up from 115° to 120° C., without danger of sugar inversion or fear that the juices will become dark in color, provided, however, that the juices being heated are sufficiently alkaline. The heating surface of the vacuum pan and

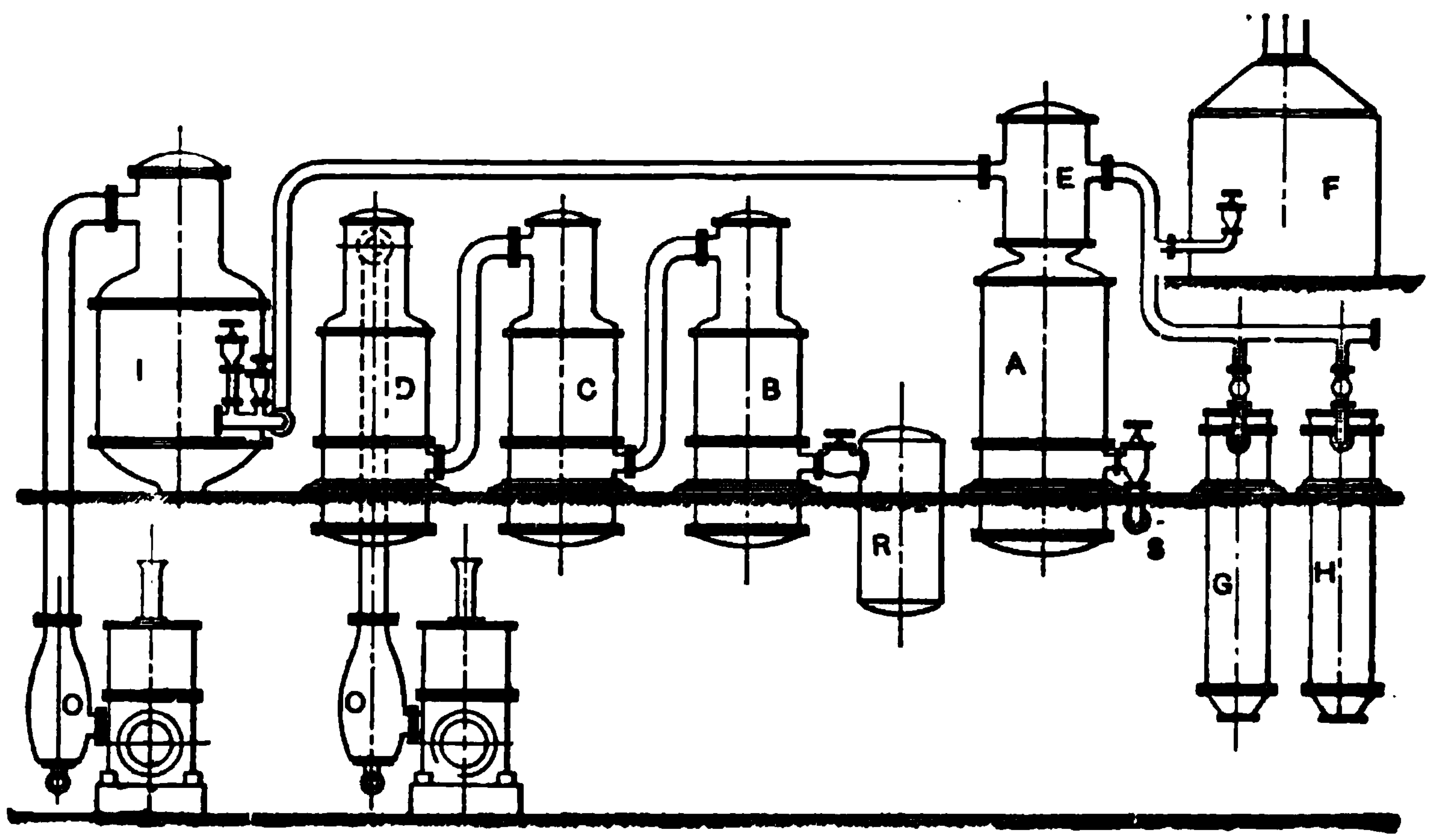

FIG. 93.—PAULY-GREINER Method.

reheaters may be comparatively small, and the steam pipes need be only o a small diameter. These facts explain the present popularity of the preliminary evaporation, notwithstanding the opposition that it met with at first.

In Fig. 93 is shown one of these combinations in which *A* is the fore-evaporator for the multiple heating, combined with the ordinary triple effect, made up of the three compartments *B*, *C*, and *D*; that is to say, the first compartment, *B*, is heated by the exhaust steam collected in *R*, and furnishes the steam to *C*, which communicates with D, this abandoning its caloric to the condenser *O*. The fore-evaporator consists of a simple-effect apparatus, sufficiently strong to resist the steam pressure introduced through *S*. The juices are pumped into this receptacle, pass through in a continuous

flow, and subsequently enter the triple effect, *B*, *C*, and *D*, in which the concentration is completed. The vapors in the fore-evaporator are at a pressure equal to about 0.25 to 1 kilo per sq. cm., and flow into *E* which communicates with the various stations where heating is needed—that is to say, with the carbonatation tank, *F*, or with the tubular reheaters, *G* and *H*, placed before the carbonatation and filtration apparatus. This same steam may be utilized during the graining in the vacuum pan, *I*, in which the heating surface as a general rule is of considerable dimensions. Finally, it may be used in the calorizator of the diffusion.

In Fig. 94 is shown a more complete application of the method. The first series of boilers, *S*, feed the steam engine, and the exhaust steam from it is used in the quadruple effect, A_1, A_2, A_3, and A_4.

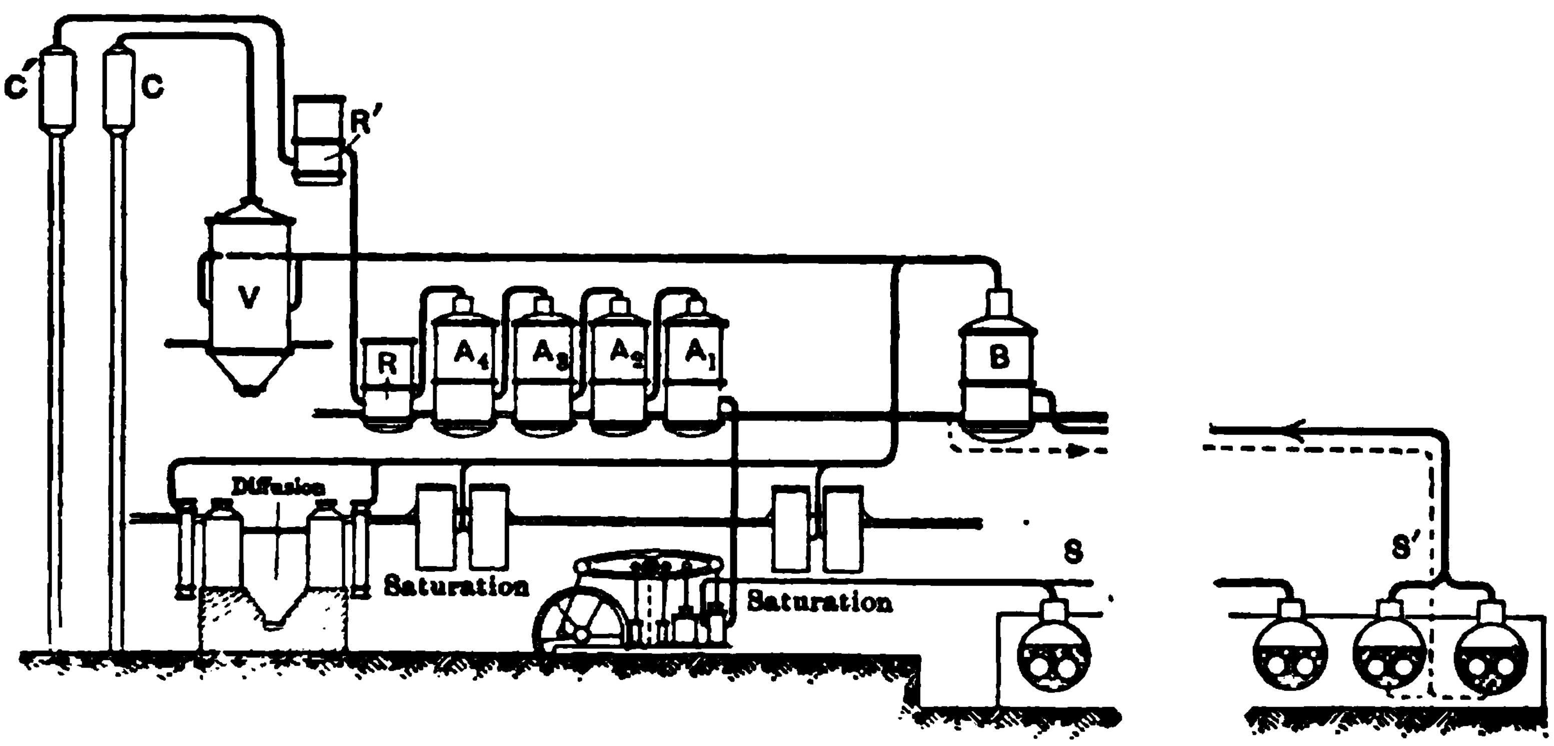

FIG. 94.—Variation of the PAULY-GREINER Method.

Before these vapors enter the condenser, *C'*, the vapors of the compartment, A_4, pass through the reheaters, *R* and *R'*, in which they yield up the greater portion of their caloric. In the low-pressure boilers, *S'*, the necessary steam is generated for the working of the fore-evaporator, *B*, the vapors thrown off from which being used for reheating the first and second saturation, and also in the coils of the vacuum pan *V*. Under these conditions there is realized an important economy of steam and consequently of fuel. The economy obtained in having two sets of boilers, one at high pressure for the engines and the other at low pressure for the fore-evaporator, will be a special subject of discussion under another caption. It is to be noted that vapor at two atmospheres pressure may be readily used in the fore-evaporator. When considered from the evaporating standpoint there would be very little advantage in

producing steam at six atmospheres instead of two, as one kilo of the latter contains 647 calories and the former 657 calories, an advantage of only one and a half per cent. If the object in view was merely to create mechanical power the arguments would no longer hold good.

When the fore-evaporator is separately considered it evidently has nothing whatever to do with the triple effect, but, sometimes when the multiple effect has to meet exceptional emergencies for a short interval of time, the exhaust steam from the collector then no longer suffices, and a certain quantity of vapor is then drawn off from the fore-evaporator, rather than use direct steam, which would be more expensive.

The reason why a multiple effect is not as well suited as a fore-evaporator to yield vapors with a comparatively high pressure is that it would be necessary to increase the pressure in the exhaust-steam collector. A certain pressure should never be exceeded as the engines with which it communicates would cease running; yet it frequently happens that the pressure in the first compartment must exceed 0.4 of an atmosphere. In certain beet-sugar factories the counter pressure is raised to one atmosphere. In such cases the greatest regularity is needed in the working of the multiple effect, for, when the slightest perturbation occurs, it necessitates opening a safety valve which permits the exhaust steam to escape into the air, and this involves considerable loss of caloric. The advantages of the fore-evaporator are consequently self-evident. Yet, while one may realize and admit its advantages, it cannot be introduced into all beet-sugar factories, as sometimes there is at one's disposal more exhaust steam than can be utilized. The waste of the exhaust steam would be greater than without it. In many cases the steam engines yield more exhaust steam than they should.

From what has been said it becomes evident that when the juice is partially evaporated in the fore-evaporator the multiple effect has far less work to accomplish in order to concentrate the juice to a given density, and the caloric lost in the injecting condenser is therefore considerably diminished. The natural consequence is an important fuel economy which reaches its maximum when the fore-evaporator can supply the caloric necessary for all the heating. When the juice remains too long a period in the fore-evaporator, where it is raised to a temperature of about 123° C., there is always a possibility of its coloration, notwithstanding the fact that there is no danger of a caramelization of

the sugar, and in order to obviate this difficulty the fore-evaporator has, in some cases, upper and lower partitions which rest upon the tube plates and force the juice to circulate from its entrance until it leaves the appliance. This arrangement prevents the juice from remaining in any one spot, and it is being constantly renewed on every part of the road travelled. The introduction into the first compartment of hot juice from the fore-evaporator, in which it is raised to a temperature higher than the boiling temperature prevailing in that section of the multiple effect, necessarily has the effect of causing the juice in question to throw off an abnormal quantity of vapor upon its entering there, and prevent just that much condensation of the exhaust vapors in the compartment under consideration.

The excess of heat stored up in that juice can be utilized to raise the temperature of the juice to be evaporated, as the latter is always a little colder than the temperature prevailing in the fore-evaporator. An apparatus (Fig. 95) is used consisting of a

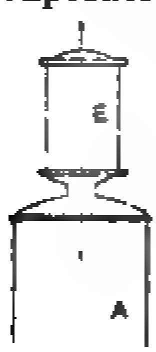

FIG. 95.—Heat Recuperator.

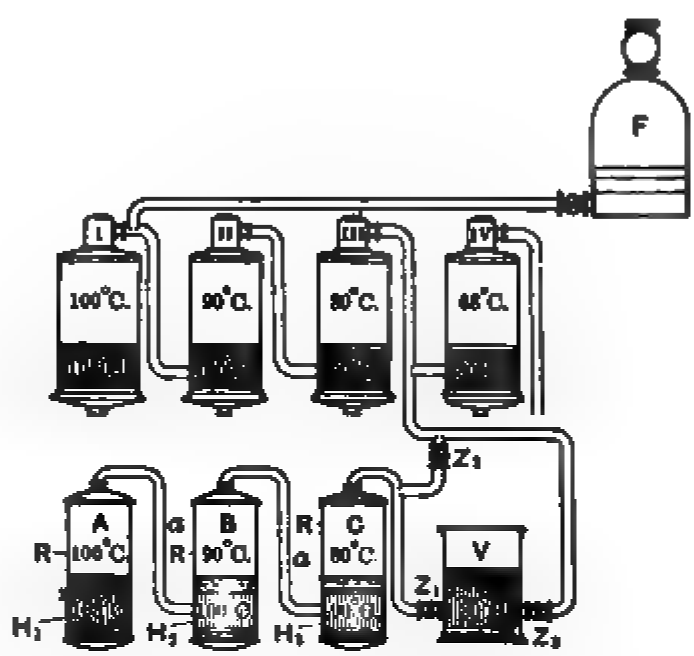

FIG. 96.—CURIN Multiple Heating.

tubular attachment, J, called a heat recuperator. The cold juice is pumped into it through K, and circulates through the tubes from bottom to top to enter into the fore-evaporator through the regulating valve L. The hot juice leaves by the valve, M, and also passes through the heat recuperator from top to bottom on the exterior of the tubes, and then through N into the first compartment of the multiple effect. The hot juice passing outside of the tube gives up a certain amount of caloric, which necessarily heats the cold juice circulating in the opposite direction,

and these enter the fore-evaporator comparatively hot. The juice on its way to the triple effect through the pipe, *N*, will be sufficiently cool not to produce in the compartment the phenomena mentioned in the preceding case.

In Fig. 96 is shown the interesting CURIN mode of multiple heating. Instead of resorting to open or closed modes of reheating, as generally used, these reheaters have the same shape and work exactly like the compartments of multiple effects. The reheating is done either with live or exhaust steam. The heating surfaces can be taken comparatively small, as the aim is not to evaporate but to heat. The vapors from the third reheater, *C*, are at a temperature of 80° C., and they may be employed for special reheating of diffusion juices, for example. This reheating is then effected in open reheaters, *V*, and the non-condensed vapors are sent into the tubular cluster of *IV*, where they assist the evaporation. If it is not desired to use the reheater *V*, the steam, instead of passing through the valves Z_1 and Z_3, may directly enter the tubular cluster of *IV*. The vapor necessary for the vacuum pan, *F*, is taken from the compartment, *I*, as in the LEXA-RILLIEUX method. The vapors and the juices in the reheating compartments, *A*, *B*, and *C*, are respectively at temperatures of 100°, 90°, and 80° C. Thus the degree of temperature at which the heating renders the most satisfactory results may be selected, and the juice is circulated in each one of these special reheaters. In the example under consideration CURIN supposes that the juices from the sulphitation tank circulate through *A*, the juices from filter presses of first carbonatation into *B*, the filtrate from the second carbonatated juices in *C*, and the diffusion juices in *V*. Nothing has been heard of any practical application of the process.

Weibel-Piccard method.—An interesting system from a theoretical point of view for the reutilization of steam, which has not up to the present time been practically adopted, but would permit the reduction of the steam consumption below 60 kilos, is based upon the fact that the vapor liberated from the juice in the first and second compartments may be compressed to the pressure of the exhaust steam used for heating by the use of suitable pumps, and may in this condition be employed for heating. Who should receive the credit of this idea remains a subject of discussion.

In 1871 FÉLIX[1] patented a process on very much the same

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[1] S. I., 13, 618, and 14, 36, 1879.

principle as the WEIBEL-PICCARD method. The latter may be applied in different ways. If during evaporation there were no non-condensable gases liberated it would be possible with one apparatus to obtain a closed cycle. The exhaust steam from the engines would enter the tubular cluster of the evaporator, the vapors liberated from boiling juices would be continuously compressed in the tubular chamber, and the exhaust steam would compensate for the heat loss in the condensed water. Evidently this mode can be introduced only when the pressure pumps can be worked by hydraulic means; and, furthermore, it follows that the vapor thus compressed would be superheated. According to CLAASSEN,[1] however, superheated steam is not utilizable for evaporating appliances, for as long as it has not cooled to its saturating temperature it acts like a gas that will slowly transmit its heat to the sides of the receptacle in which it is placed. Even with the injection of water the superheat will not condense quickly enough. TOCKEI[2] states that by the WEIBEL-PICCARD mode there follows a superheating of about 13° C.

MALANDER, however, who operated a multiple effect with supersaturated steam declares that no difference in the working of multiple effects was noticeable when saturated steam or superheated steam at 230° C. was used. CLAASSEN points out another objectionable feature, namely, that as the compressing pumps should be liberally lubricated, the compressed vapor will contain considerable oil, which deposits upon the pipes and thus diminishes their heat transmission. MALANDER takes exception to this, and says that there is no reason for excessive oiling of the pressure cylinder, any more than for the giving of especial attention to the engines, the exhaust of which is utilized in evaporation, and does not cause any grease clogging of the portions with which it comes in contact.

There is certainly ample authority for the belief that the WEIBEL-PICCARD mode has a possible practical future. The principle has already been working at the salt establishment of BÉVIEUX (Switzerland)[3] since 1878. HORSIN-DÉON[4] says that a beet-sugar factory having free motive power could compress the vapors on their way to the condenser, so that the sugar plant

[1] CLAASSEN, Zuckerfab., p. 150, 1901.
[2] B. Z., 7, 141, 1883.
[3] Oe.-U. Z., 8, 479, 1879.
[4] HORSIN-DÉON, Traité II, 2, 658, 1901.

need not consume more than 45 kilos of coal per ton of beets sliced. This would mean a saving greater by at least 20 to 25 per cent than is realizable in the most modern and best-constructed sextuple effect.

In Fig. 97 is illustrated the practical working of the process under consideration, in which there is a reutilization of the vapor for evaporation. The live steam used in the cylinder, *A*, gives sufficient power for the compression. The exhaust steam from the engine, *A*, passes into the first compartment of the triple effect, *C*, *D*, *E*. The vapor obtained from the compartment, *C*, is used first of all for the evaporation of the juice in *D*, the vapors from which are in the same way utilized in *E*. The vapors from the

FIG. 97.—WEIBEL-PICCARD Method.

last compartment are condensed in *F*. A portion of the vapors from *C* are drawn off through *H* into the compressor, *B*, from which they are forced back into the tubular cluster of *C*.

In Fig. 98 is shown another application of the same idea. The vapors escaping from the tandem motor with double expansion, *C* and *C′*, are utilized to evaporate the juice in the triple effect, *A*, *A′*, *A″*. The live steam from the boiler, *G*, passes into the cylinder of *C*. Alongside of the triple effect works a special apparatus, *B*, the vapors from which are drawn off by the pump, *P*, and forced back into the heating chamber of *B*. In order that practical results may be obtained it is necessary to replace the caloric lost in the water of condensation either by live or exhaust steam.

URBAN'S[1] experiments point to the possibility of using a double-effect evaporator by resorting to the WEIBEL-PICCARD mode,

[1] B. Z., 7, 181, 1883.

in which, however, a portion of the vapors from the first compartment are compressed in the tubular chamber of this same compartment. There are evaporated 4.4 kilos of water for one kilo of exhaust steam taken from the exhaust-steam collector. It is interesting to note that in an ordinary double effect one kilo of steam will evaporate 1.9 kilos of water, while for a triple effect the evaporation is 2.85 kilos of water, in a quadruple effect, 3.7 kilos of water, and in a quintuple effect, 4.3 kilos.

It has been proposed by SELWIG and LANGE that injectors be used to force steam into the heating portion of the tubular cluster of one of the compartments of a multiple effect, the steam

FIG. 98.—Variation of WEIBEL-PICCARD Method.

used for the purpose to be taken from a receptacle where the tension is lower, as, for example, the liberated vapor from the compartment that follows in the series. It is claimed that under these circumstances the latent heat of the vapor drawn off will be added to that of the additional live steam injected, and that an important economy will result. This method has been put into practice by MLOCHEWSKI.[1] The vapors of the first compartment are used again after being mixed with live steam. The combination is effected by the use of an injector. To this injector is brought a pipe taking up a portion of the vapor liberated by the juice during boiling. The vapor is drawn by suction into the injector by live steam, which must always be used during evaporation in plants where the exhaust steam is not in excess. The live steam in question compresses the more or less expanded

[1] C., 10, 677, 1902.

vapors taken from the evaporating appliance. They can thus effect a boiling of the juice in the first compartment and utilize its latent heat of evaporation in the multiple effect. Under these circumstances it becomes possible to use the vapors of the second compartment for a second time. It is claimed that by such a procedure the activity of the first and second compartments of a triple effect is greatly increased. The utilization of the last compartment of a multiple effect by this mode would offer some difficulty.

CLAASSEN[1] discusses with considerable authority the question of reutilization of low-pressure steam from the multiple effect for the evaporation by the use of an injector. He says that it is not possible to again use the vapors of the last compartment, as the steam injected will not force the pressure of the vapors to more than 0.8 of an atmosphere. Consequently, only the vapors from the compartment before the last may be again utilized; and even then to obtain some practical results it is necessary that the combination be most favorable for the working of the injectors. For example, the entrance steam valve should be entirely open

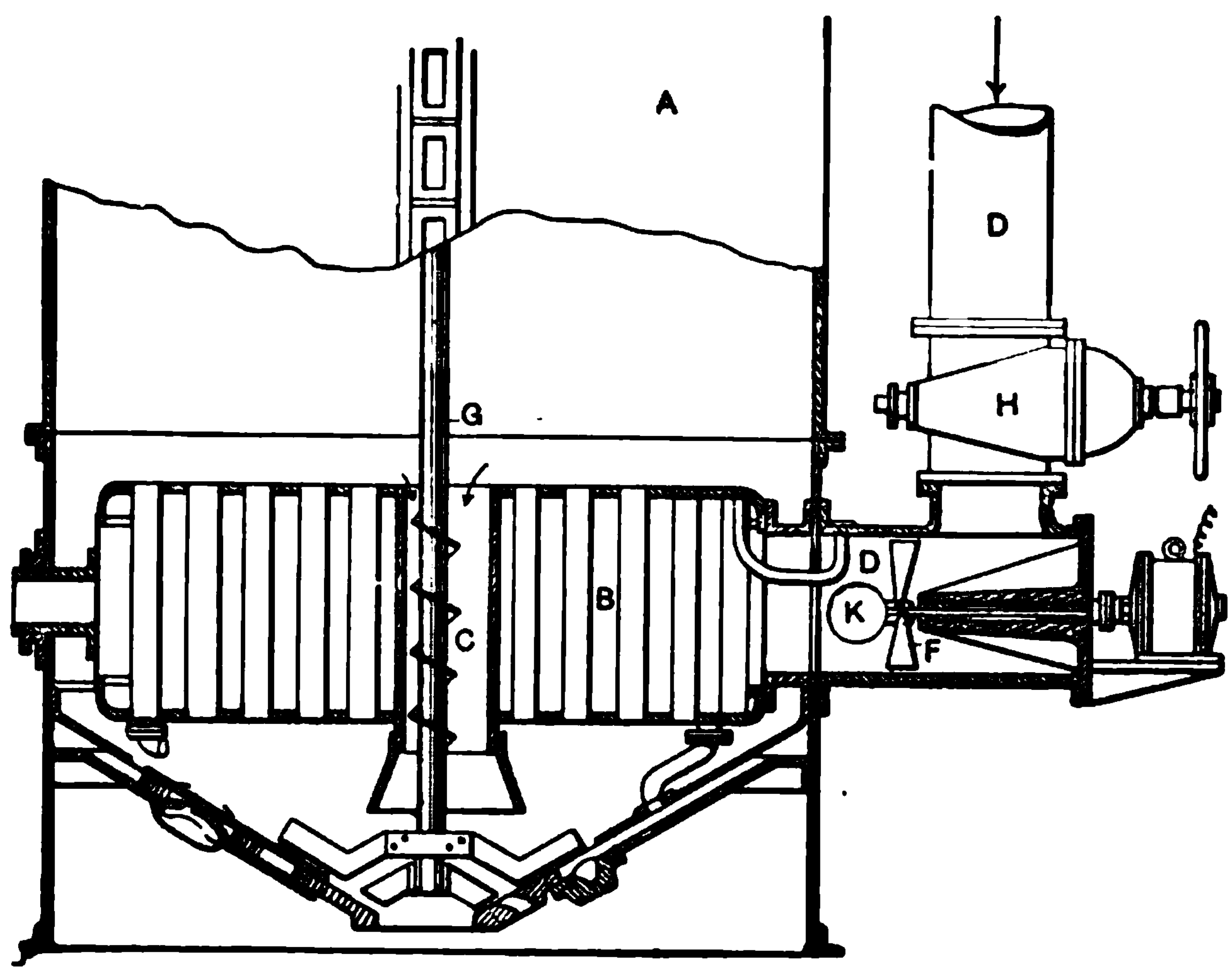

FIG. 99.—FREITAG Vapor Recuperation.

and the pressure of the injected live steam should be at least five to six atmospheres. When there is an irregular evaporation this can only be realized by placing upon the heating chamber of the first compartment several injectors of different sizes, which are used simultaneously or separately, according to the importance

[1] Z., 52, 781, 1902.

of the evaporating work to be accomplished. The caloric of the live steam is entirely utilized, for the reason that the loss of heat through expansion is compensated for by an increase obtained in compressing the vapor at low pressure. In the examples given in the first compartment of a quadruple effect are compressed the vapors taken from the second, from which there results an economy of 3.8 kilos of steam per 100 kilos of beets worked. If the vapors of the third compartment are compressed in the same manner, the resulting economy is said to be 5.2 kilos per 100 kilos of beets sliced. These data form an argument for a practical trial of the idea.

The drawing herewith (Fig. 99) illustrates very much the same principle, but instead of injectors a small propeller put in motion by an electromotor is used to force the vapors into the evaporator.[1]

Multiple-effect reheaters.—For the reheating of juices at different stages of sugar extraction from beets, the reheaters already described under another caption are used. Certain advantages

FIG. 100.—REBOUX Evaporator and Reheater.

are also claimed for the use of special reheaters placed between the different compartments of a multiple effect. Fig. 100 shows one of the REBOUX evaporating combinations, in the interior of which is arranged a reheater for the application of the LEXA-RILLIEUX method. The vapors liberated from the juice in *A*

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[1] S. B., 25, 73, 1904.

run through B into the reheater C, then through D into the next compartment of the series. When for any special reason the reheater is no longer needed, the valve E is closed and F opened, this allowing the vapors to circulate from one compartment to the other, as they do in the standard multiple effects. The water condensing on the surface of the tubes of the reheater is collected by a sheet-iron disk and escapes through the pipe, q, into the purger G.

Generally it is not customary to adopt this mode of heating between each compartment of a multiple effect. One reheater, however, should be placed in the passageway of the vapors from the last compartment to the condenser, and for this purpose the horizontal type is generally used. Circulating through it are the diffusion juices having a temperature of 30° C., while the vapors from the effect are at 60° C. In many factories one hesitates to use these appliances for this purpose, for the reason that the liquid to be heated is at a pressure greater than that of the vapors used as a heating medium, and there is always danger, under these circumstances, of losses of juice through leakage. By repeated examination of the water of condensation one may follow the existing conditions very easily—suitable tubes and cocks allowing samples to be taken.

Purging cocks are necessary to give free exit to the gas that is generally formed, as the cold diffusion juice from the measuring tank contains considerable air, and this, if allowed to collect, could influence the circulation in a very important degree. In cases where the measuring tank is at an elevation considerably above the reheater, a pipe open on top extending to an elevation a little above the tank under consideration answers the purpose; this obviates the constant opening and closing of the purging cock.

In these special reheaters the combination should always be such as to allow the condensed water an easy escape, otherwise it would influence the vacuum existing in the multiple effect. In cases where the pipe connecting the reheater and the last compartment of the effect is bent downward, the lowest portion of the bend should have a pipe through which the condensed water may be removed. The vapors that are not condensed in the reheater pass into the condenser. In case the exit pipe of these vapors is not placed on the upper part of the heating chamber, special precautionary measures should be taken for the removal of the ammoniacal gases through a pipe passing from the top of the heating chamber in question to the condenser.

CHAPTER VII.

PRACTICAL CONSIDERATIONS.

Starting a multiple effect.—The air pump is set in motion and the water-injecting valve of the condenser is opened. The large valve between the last compartment of the effect and the condenser is then gradually opened, and all the ammoniacal gas-exit cocks are thrown open, so that the vacuum may be obtained successively in each of the compartments. The ammoniacal pump is started after making sure that the valves of the pipes communicating with each other are closed.

Juice is successively drawn into the compartments, so that they may be filled with the least possible delay. In case the evaporation is to be conducted on the basis of a high level, the last compartment should contain less juice than the others, so that the juice drawn off may have the desired concentration from the start.

As soon as the first compartment is full of juice the exhaust-steam safety valves are regulated. The steam valves of this compartment are very gradually opened, and the boiling soon commences. At the start, MALANDER says, the vacuum in this first compartment may be as high as possible, as this naturally hastens the boiling, and the interval of time before the next compartment is in full activity is thus much lessened. But as soon as the boiling becomes too active in the second compartment the ammoniacal-gas valves of the heating chamber of the said compartment are gradually closed. At that instant the air will have been driven off. The vacuum in the first compartment is lessened and from this time on is kept in its normal condition, which necessarily means that the resulting vapors will rapidly boil the juices in the second compartment. The operations in the other compartments do not differ from those in the first.

During the interval of time needed for the full starting of the multiple effect there necessarily occurs a considerable accumulation

of juice, hence it is recommended that the evaporation be begun as soon as the first carbonatated juices can be introduced into the apparatus.

When the evaporation is conducted at a low level, this juice accumulation is very much less. In order to get the multiple effect in full activity upon the arrival of the juices to be evaporated certain factories start the apparatus with water before juice is available. This mode evidently causes some dilution of the juice, and its advantages and disadvantages are open to discussion.

Normal working.—As soon as the juice in the last compartment boils, the regular working of the apparatus may be said to begin. Under another caption has been explained the manner in which the juice circulates in a multiple effect. It is interesting at this point to follow some few of the phenomena which are readily observable. When the juice to be evaporated enters the compartment where the boiling temperature is lower than that of the juice itself, large steam bubbles will be formed which might result in important losses through entraînement. By having the entrance suction pipe for the juice from one compartment to another at the bottom of the receptacle the difficulty may in a measure be overcome, and the bubbles formed may help the circulation of the juice. There are advantages in having the juice communication between the compartments as low as possible, as the passage of the juice from one compartment to the next is thus very greatly facilitated. As the juice must not rise to a certain height, it runs from one section into the next, even if the difference of vacuum in the two compartments is very slight.

Reversing the circulation.—The idea of reversing the circulation in a multiple evaporator has been proposed by Camuset and Cailliatte,[1] the juice entering the effect in the last compartment, and the syrup being drawn off from the first. This change in the method of working offers special advantages, but has, on the other hand, certain objectionable features. The ammoniacal vapors are more readily carried by the vapors into the condenser, and, the heat transmission of the last compartment being less, it is partly compensated for by the higher specific heat of the juice.

The high temperature at which the syrups leave the apparatus is favorable to their filtration. The losses through entraînement are lessened by this mode, as the syrups boil in a medium where the

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[1] Bull. Synd., 18, 751, 1894.

maximum pressure prevails, and consequently where the vapors have the least volume and the least velocity. This mode, however, necessitates a series of pumps in order that the liquid may pass from one compartment to the other, and pumps always entail certain perturbations in the general working of the apparatus. This method has been applied with success in the LILLIE multiple effects.

Level of the juice.—The passage of the juice of a multiple effect from one compartment to another should be continuous and not by jumps and starts. The person in charge soon learns to regulate the communicating valves in such a way that it is seldom necessary to change their position, provided that the juice flows regularly to the evaporating apparatus. The juice is kept at the desired level, which depends upon whether the apparatus is working at high or low level, and the concentrated juice is continuously drawn off from the last compartment in such a way that the level always remains the same, and the exit flow always has the same degree of concentration. To accomplish this no special expert labor is needed, any one in and about the factory when once taught can accomplish the desired end. When the valves have been properly regulated, the level and the concentration will vary only in a very slight degree. Certain rectifications must, however, be made from time to time.

Several automatic devices for juice regulation have given satisfaction, but for various reasons they have never met with the favor one might suppose. However, in the LILLIE evaporator they have met with great success.

In Fig. 101 is an outline drawing of an apparatus of this kind. Suppose the evaporation to be conducted at low level: A receptacle, B, contains a float, S; it is in connection with the lower and upper part of the compartment, A, through the pipes (a) and (c) respectively. When the juice falls lower than the level XX, the float, S, works the valve, V, which allows the juice to enter the compartment, and when the level is normal all communication ceases as the valve, V, is closed again by the float, S.

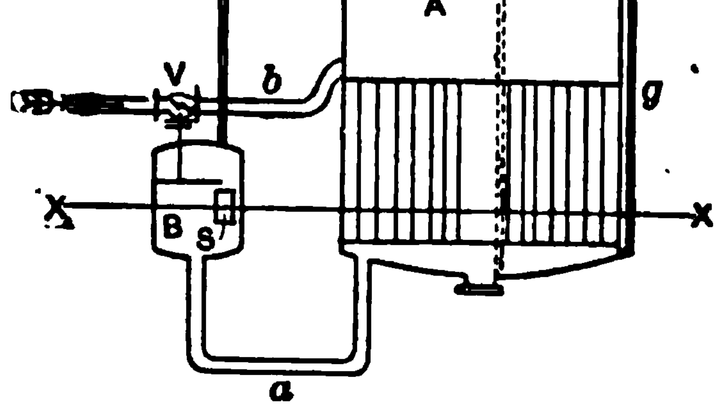

FIG. 101.—CLAASSEN'S Level Regulation.

The LEURSON regulator is also very simple in its construction.

It consists mainly of a box containing a float which acts upon a valve. The juice circulates from one compartment to the next through these regulators. When the level is too high the float cuts off communication with the juice tank or the preceding compartment. The scheme shown in Fig. 102 gives a very clear idea of the manner in which the floats work, as attached to each section of the apparatus. The float *C* regulates the volume of syrup being drawn off; it works when the density of syrup becomes too high in *III*, but in the opposite direction from *B*. The pump, *E*, is then set working

Fig. 102.—Leurson's Level Regulation.

and the syrup is drawn off. Floats of the same kind may be used to regulate the exit flow of the water of condensation.

Vacuum in different compartments.—Provided all the essentials mentioned in the foregoing are present, there will exist a normal vacuo in each of the compartments, the variations of which will depend upon the pressure of the escaping steam, the vacuum in the condenser, or the opening of the ammoniacal-vapor pipes. Experience alone can determine to what extent these cocks should be opened. No data are known by which to determine the desirable limit for the removal of these vapors. In cases where pipes of an exceptionally large diameter are opened beyond a certain limit, the desirable difference of pressure between the two compartments will no longer exist, and the vapors will flow to the condenser without being properly utilized.

In many factories it is customary to have a fall of pressure about the same in each compartment; for example, a vacuum of 0.2, 0.5, and 0.8 atmospheres, in the first, second, and third compartments respectively, corresponds in practice to falls of temperature of 93°, 81°, 61° C. It may be noticed that between the second and third compartments a notable difference exists. When it is desired to increase the efficiency by introducing more steam, the temperature and pressure of compartments *I* and *II* will necessarily increase, and the difference between *II* and *III* becomes even greater than in the foregoing example. Upon general principles it may be said that the difference between the vacuum and the temperature will finally become self-regulating within reasonable limits. However, it may happen that at a given moment the difference between the temperature of the two communicating compartments decreases considerably, and this would indicate some abnormal condition of working, due probably to the accumulation of non-condensable gases, condensed water in the calandria, or incrustations upon the tubes coming in contact with the juice.

According to HORSIN-DÉON,[1] the temperatures of the steam in the exhaust collector and in the four compartments of a quadruple effect are as follows: Exhaust collector, 112° C.; 1st compartment, 105.5° C.; 2d compartment, 96° C.; 3d compartment, 84.5° C.; 4th compartment, 67° C. In a quintuple effect, 112° C.: 1st, 106° C.; 2d, 99.5° C.; 3d, 91° C.; 4th, 79° C.; 5th, 60° C.

Regulating steam introduction.—In regulating the quantity of steam introduced in the first compartment, one must take into consideration the rapidity at which the evaporation is to be conducted. If the exhaust steam from the collector is not sufficient to meet the demands at a given moment, then live steam must be used. Precaution must be taken not to raise the pressure in the exhaust collector to a point that will influence the working of the engines with which it is connected. DESSIN[2] says against many other experts that the increase of pressure in the exhaust-steam collector does not increase the efficiency of the apparatus in any important measure.

In some cases the first compartment is worked by the introduction of a certain quantity of live steam into special coils or apparatus connecting with it. As the volume of the exhaust

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[1] HORSIN-DÉON, Traité II, 2, 645, 1901.
[2] Bull. Synd., 18, suppl., 13, 1893.

steam from the machines of a beet-sugar factory is generally not sufficient for the evaporation, its entrance valve need very rarely be closed, except when the volume of juice entering the multiple effect in a given time is reduced; the non-utilized steam should then escape into the air through a safety valve of suitable dimensions. It is not advisable to introduce water into the apparatus during this emergency, as this would lessen the purity of the juice owing to the foreign substances that water generally contains.

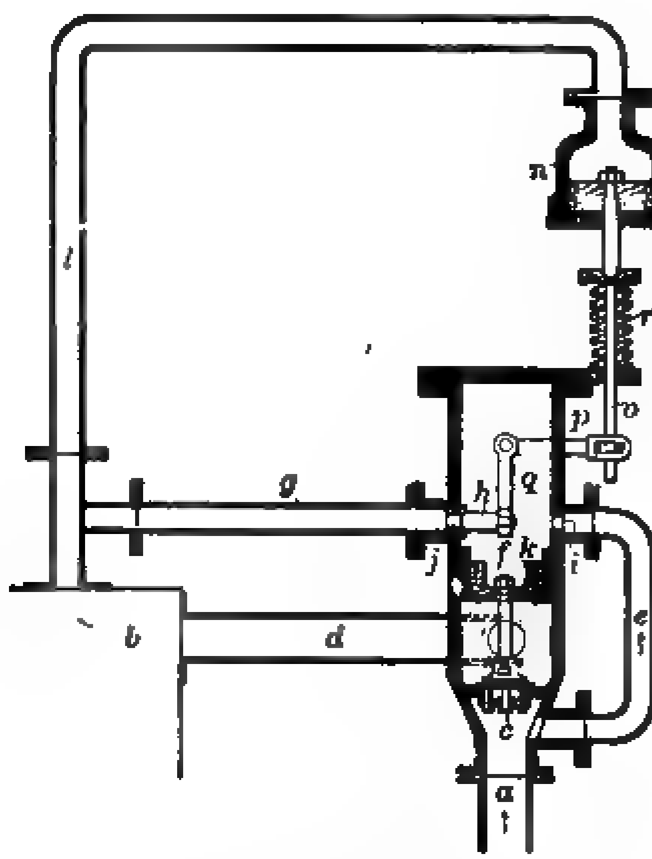

Fig. 103.—Wernicke Feed Valve.

Fig. 104.—Schoof Pressure Regulator.

Sometimes, with the view of regulating the quantity of live steam coming to the assistance of the exhaust steam used during evaporation, special automatic valves are used that are adjusted to the pressure existing in the apparatus into which the live steam is to be introduced. The Wernicke (Fig. 103) feed valve consists of a small piston, *B*, which falls when the pressure of the steam chamber is lessened; the column, *C*, of water or mercury follows this motion, acts on the lever, *D*, the rod, *E*, and the balanced

valve contained in A, which is then opened and live steam enters the calandria. When the desired pressure is reached the piston, B, and the steam valve just described are closed. By this arrangement the pressure may be regulated by the quantity of water or mercury contained in C.

In Germany several types of valves have been proposed varying more or less from the one described. The SCHOOF pressure regulator (Fig. 104) is one of them. It consists of a valve, c, which allows the passage of such a volume of steam as is requisite for the heating of the first compartment of a multiple effect when the apparatus is first started. At the same time a smaller volume of vapor passes into the tubular cluster through e, j, and g. When the compartment is already under a certain pressure, the valve, c, is forced downward owing to the pressure exerted upon k by the vapor coming from b through the pipe g. Under these conditions the steam entering through a passes only into e, then through a valve, j, and continues through g into b. If the pressure becomes still greater in b it will press upon the piston, n, and the levers p and q, and finally close j, under which conditions all communication with the steam boilers ceases. It is claimed that the working of j may be regulated with great accuracy by the means of the spring r.

The DULAC-RILLIEUX valve (Fig. 105) consists of an ordinary valve, A, on the top of which is a metallic truncated portion, B. If the steam is at a desired pressure when escaping through the valve it will react upon B, and bring about an equilibrium, under which circumstances its opening will be proportional to the difference of pressure on the two sides of A. This device is very sensitive in its working. The valve in question is loaded with a counterpoise, F (acting through the lever E, and the rods C', C), which keeps the valve upon its seat. A bronze cylinder, D, with circular grooves slides in a bronze sleeve, and is substituted for the packing. The steam, after escaping from B, enters the tubular cluster through G.

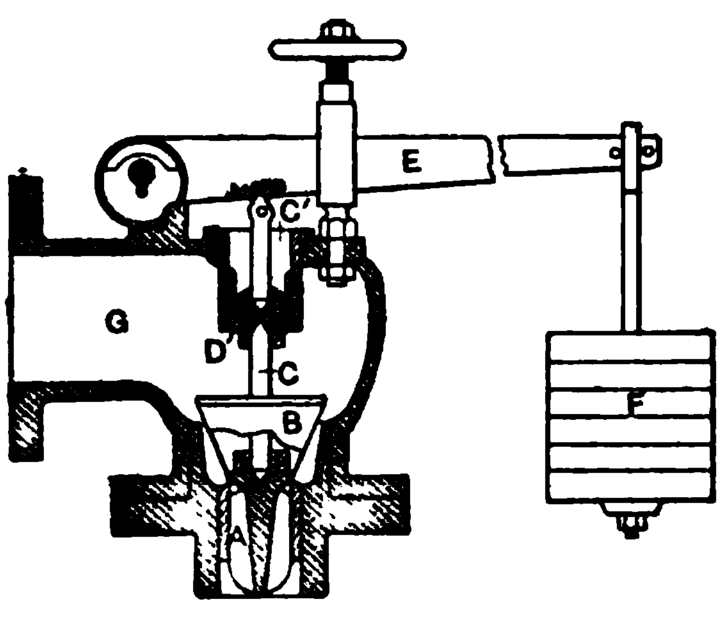

FIG. 105.—DULAC-RILLIEUX Valve.

FRAEMBS and FREUDENBERG[1] combine the steam entrance valve

[1] D. Z. I., 24, 1402, 1899.

and the valve for the evacuation of condensed water, so that any motion given to the one will be immediately transmitted to the other. Under these conditions the openings of the valves regulate each other, and irregularities in their working are eliminated. In some other appliances the admission of the steam is not regulated by the prevailing pressure in the tubular cluster, but by that in the vapor chamber of the compartment.

Density regulator.—If, by starting the multiple effect, the concentrated juice or syrup from the last compartment is not drawn off until it has a density corresponding to 30° Bé., there will be an abnormal accumulation of juice in the other compartments; and therefore this drawing-off should commence before the standard concentration has been reached, say at 20° Bé., and the ideal conditions will be attained by degrees.

Syrup samples.—To obtain a sample of the juice during its several phases of concentration, a test tube is used which communicates with the juice-level indicator. The spindle used should evidently be graduated for high temperature, say 65° C.; otherwise its reading is not correct. In Fig. 106 is shown this arrangement for sampling syrup. The syrup-level gauge, *e*, communicates with the compartment of multiple effect by means of the cocks, *a* and *b*. When *e* is full of syrup the cocks, *a* and *b*, are turned so as to occupy the position ⊣. Air then enters through *c*, and the syrup may run off through *d* into the eprouvette, *f*, holding the spindle. The eprouvette may be emptied by placing *b* in the position ⊤. Sample for analysis may be drawn from another cock to be connected with the lower part of the test tube.

Numerous appliances have been used permitting a continued density determination. SCHANDER[1] brings into a *V* pipe a small pipe communicating with the force pipe of the syrup pump. One of the arms of the *V* is slightly higher than the other, thus exerting a slight pressure which facilitates the flow over the other arm. The latter contains an areometer, allowing the pan man to ascertain at any time the exact density of the syrup. The juice or syrup running off is collected and sent back to the pump.

The HECKMANN apparatus (Fig. 107) works upon the same principle, but is continuously under vacuo. It consists of a glass receptacle, *d*, hermetically closed, in which there is the same vacuum prevailing as in the compartment, *A*, with which it com-

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[1] C., 7, 940, 1899.

municates through the small pipe *e*. The concentrated juice is drawn from *A* by a pump and passes through the pipes *m*, *o*, *c*. Upon *o* there is a branch pipe, *n*, communicating with *d* through *f*, and the liquid that overflows is collected in *b*, and returns to the pump through the main pipe. A spindle is placed in the test tube *f*, and through the glass of *d* the density may be read. Two valves, *i* and *k*, allow the syrup to be drawn from the pump without passing through *d*.

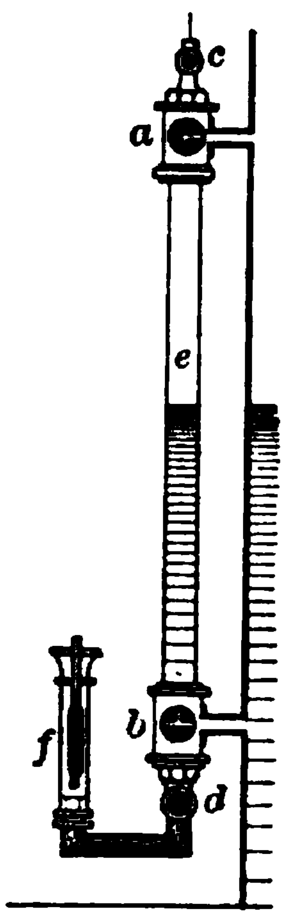

FIG. 106.—Syrup Sampler.

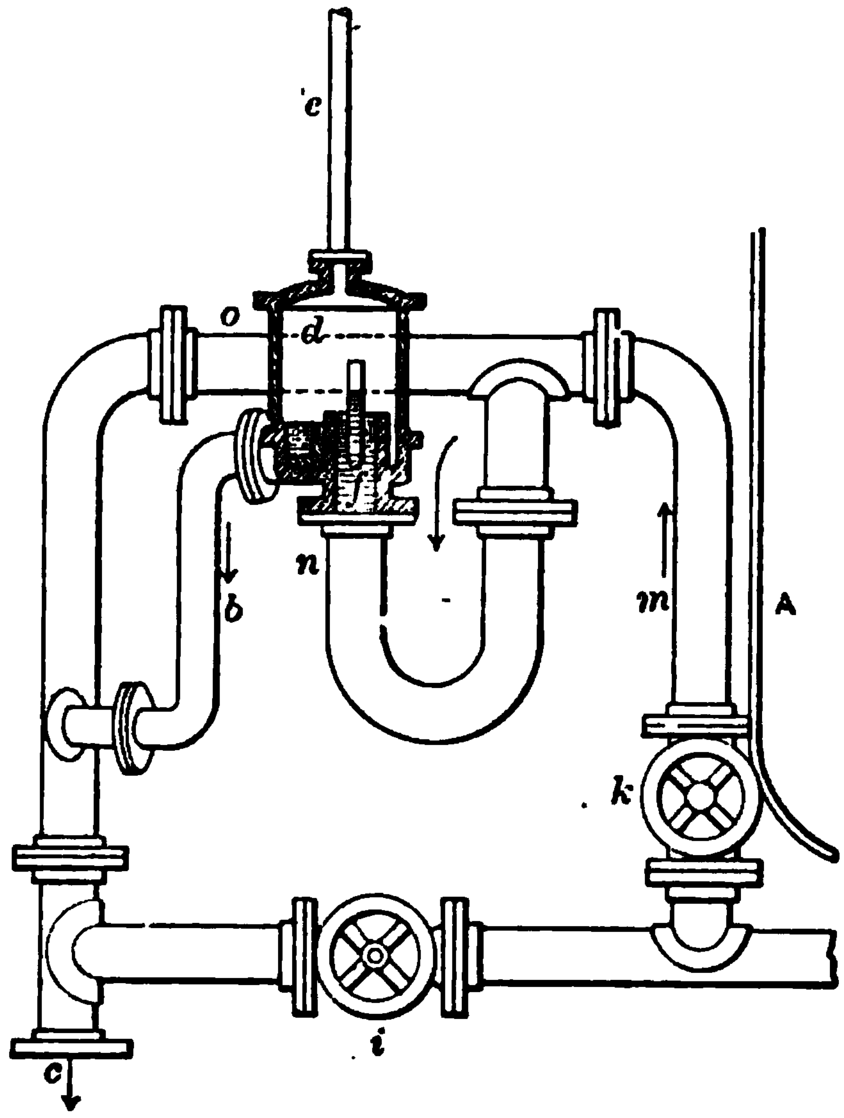

FIG. 107.—HECKMANN Syrup Sampler.

Density indicators.—The TOURNEUR[1] density indicator (Fig. 108) is based upon the principle that when two tubes, *m'* and *n'*, of the same section, are plunged into a liquid at a determined distance from each other (*m–n*), they will be under a difference of pressure varying with the specific weight of the liquid. The apparatus consists of two reservoirs, *A* and *B*, communicating by a glass tube *T*. From each of these reservoirs run tubes, *m'* and *n'*, of one centimeter section, which penetrate the liquid being evaporated to depths one meter apart. The glass tube being filled up to a certain height with any liquid, water for example, the passages of the small pipes, *U*, are opened for the entrance of the air into the two reservoirs. When this opening is once regulated, it becomes possible

[1] Z., 50, 101, 1900.

to stop the water in the glass tube at any height desired, representing each time a density determined in advance. With the slightest variations of density, there will follow a variation in levels, and the densities are read from a graduated scale upon the glass tube, which may be graduated by practical experiments.

There is another type of density indicators, as designed by Divis (Fig. 109). A float, *P*, is suspended by a wire, *D*, to a spring, *J*. The float always remaining submerged, its reaction upon the spring will depend upon the density of the syrup. The wire, *D*, is attache at *I* to a portion of a cog-wheel, which works a pinion. Upon the pinion is a pointer, *A*, which indicates upon a dial the varying

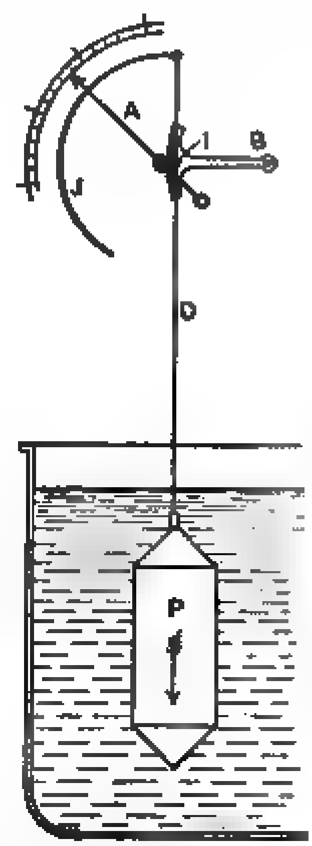

Fig. 108.—Tourneur Indicator.

Fig. 109.—Divis Density Indicator.

densities of the syrup in which *P* is submerged. The graduation of the dial should be determined by experiment. The Passche[1] arrangement worked upon very much the same principle as the Divis combination, with the advantage, however, that an automatic correction of temperatures on the density readings was made, and consequently the corrected density was read upon the scale.

Density regulators.—Other devices permit the syrup to be drawn off only when the desired density is reached. The Koertum density regulator (Figs. 110 and 111), as applied to juices being

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[1] D. Z. I., 23, 791, 1898.

concentrated in a multiple effect, consists of a cylindrical receptacle, *a*, which is connected by two tubes with the evaporating apparatus.

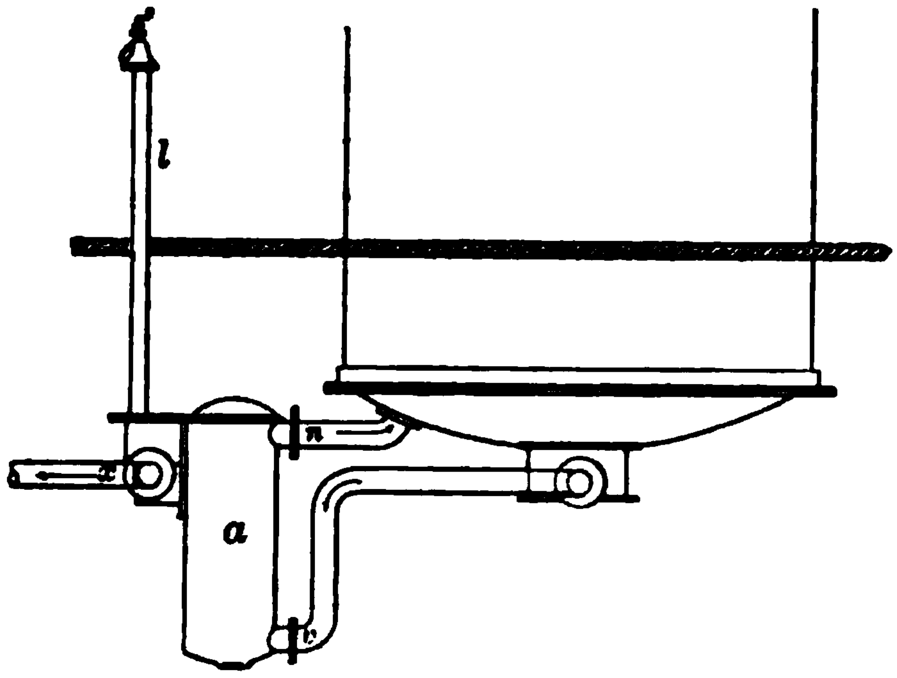

FIG. 110.—General View of KOERTUM Density Regulator.

The juice enters by the lower pipe, *o*, and leaves by the upper, *w*, owing to the density and temperature. The float, *b* (Fig. 111),

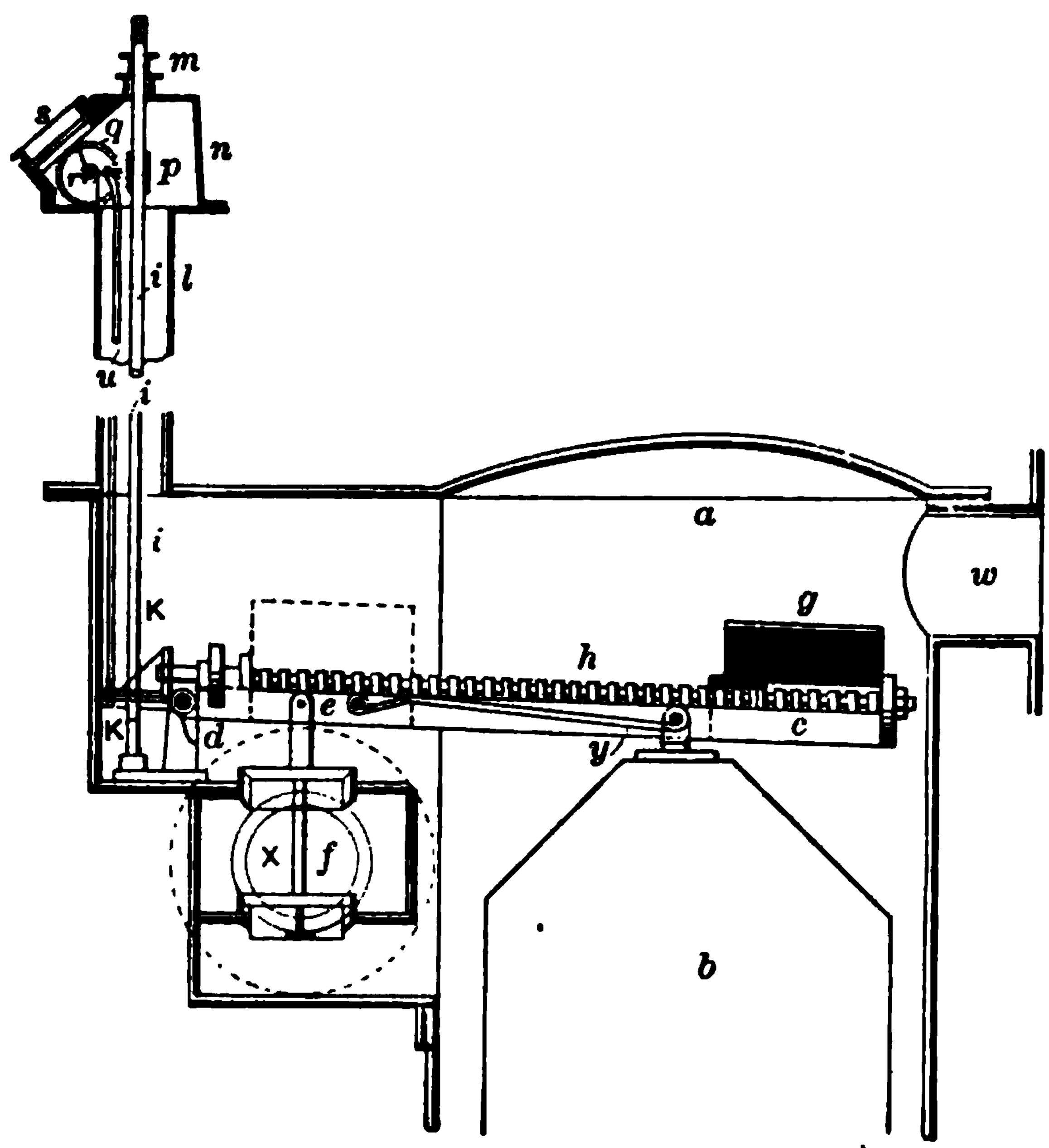

FIG. 111.—Detail of KOERTUM Density Regulator.

placed in the interior of the receptacle *a*, raises a balanced valve, *f*, as soon as the desired concentration is obtained. Upon the lever, *h*, a counterweight, *g*, moves with the assistance of a screw, *h*. The

position of this weight determines the up-and-down motion of *b*, and is decided upon in advance. The counterpoise's position, and consequently the working of the apparatus, may be regulated from the outside by the means of a rod, *i*, having a top crank and conical gearing, which forces the screw-threaded rod, *h*, to revolve. The weight, *g*, is at once set in motion, its position on the lever being indicated upon the dial, *r*, set in motion by the endless screw, *p*. If the indicator says "closed," the solution is not concentrated enough; and if "open," the concentration is sufficient, meaning, at the same time, that the valve connecting with the *monte jus* was open. When this regulator has a pump attachment it must undergo a few modifications to meet the special requirements that then present themselves. On the LILLIE evaporator, there is a very simple density regulator, mentioned under another caption.

It is shown by practical experience that it is not desirable to push the concentration beyond a certain limit. If carried beyond 60° Brix (33° Bé.) a decided elevation in the boiling point and an increase in the viscosity of the juice results, with an increased pressure in all the compartments of the multiple effect. The useful fall of temperature decreases and the increase of viscosity decreases the coefficient of transmission; this reduction is two-thirds for a syrup at 50° to 60° Brix, while, for a thick syrup of 70° Brix, the coefficient is only one-third of what it originally was. It is frequently maintained that the lowering of the specific heat of concentrated juices has an influence on this coefficient, but CLAASSEN considers that this hypothesis is incorrect.

It frequently happens that, when excessive concentrations are reached, the point of saturation of sugar solutions will have been exceeded, and this brings the sugar about to crystallize in the pipes, valves, etc., causing numerous complications. The concentration in the other compartments cannot be regulated with the same ease, as it depends upon numerous factors. In case exceptional demands are made upon the multiple effect, the syrup is drawn off at a lower density than previously mentioned. If the syrup has a tendency to become excessively concentrated, a copious supply of juice may be drawn into the last compartment; the condition, however, being that a corresponding quantity is pumped off with the least possible delay. On the other hand, if the syrup in the last compartment of the effect is too diluted, the entrance valve of the preceding compartment and the valve connecting with the syrup pump are partly or entirely closed. From what has been said in the foregoing, it

may be concluded that the surveillance of the working of the apparatus should be based upon the following rules:

First, that the amount of steam used shall correspond to the volume of juice to be evaporated; second, that the pressure in the first compartment and in the exhaust-steam collector shall not exceed a limit determined in advance; third, that the vacuum in the compartment of the concentrated juice shall be kept at the uniform standard; fourth, that the level of juice in all the compartments of the multiple effect shall be kept as low as possible; fifth, that the concentrated juice shall be regular y drawn off at a uniform density from the last compartment. If these conditions are maintained, most of the other essentials take care of themselves.

Handling a Pauly-Greiner multiple effect.—No special instruc-structions are needed to handle the PAULY-GREINER multiple effect, with its fore-evaporator, which supplies the requisite vapor for the first compartment of the effect. Care should be taken that the pressure of the exhaust steam does not become abnormally high. When the juice is run from the fore-evaporator into the effect, there follows a decided fall in the prevailing vacuum of the first compartment, which is due to the liberation of a certain amount of vapor, as previously explained. Less condensation of the exhaust steam in the calandria results, and the pressure in the tubular cluster and in the exhaust-steam collector will necessarily increase. To prevent losses through the safety valves, the quantity of vapor taken from the fore-evaporator into the first compartment should be lessened, if any is taken at all.

CLAASSEN proposes that only a portion of the carbonatated juice shall be drawn into the fore-evaporator, under which circumstances the volume of juice at high temperature entering the first compartment of the effect becomes very much less. It is consequently recommended that there be introduced into the fore-evaporator a volume of juice that will keep within a limit of concentration not higher than 15° to 20° Brix. The remaining juice is drawn into the first compartment of the multiple effect, where it comes later in contact with that from the fore-evaporator.

In certain cases, it is impossible to utilize in the multiple effect all the exhaust steam from the collector, and under these circumstances the working of the fore-evaporator should cease. Upon general principles, the fore-evaporator should be actively worked only when the multiple effect is in full running order, as it then gives important assistance in furnishing all the supplementary caloric

needed. During the first stage of the fabrication, the juice in the fore-evaporator is brought to 100° C. without boiling. When starting and when working up the juices, as is the case every time a long lasting stoppage is expected, direct steam is, however, needed for the vacuum pan or the reheaters, while the first compartment of the multiple effect and the fore-evaporator are not yet in full activity. The steam valves placed on the reheaters and vacuum pan with this view should be very carefully watched, so as to prevent their being unnecessarily opened. For this reason, the hand wheels should be removed, or should be under lock and key, during the regular work. CLAASSEN advises, instead of using a steam valve for each apparatus, to have one large valve, either on the pipe conducting exhaust steam used for heating, or upon that carrying the vapors of the fore-evaporator, as one valve is more readily looked after than several.

Requisites for the fore-evaporator.—When starting the fore-evaporator, all the air- and water-purgers upon the heating chamber should at first be left open. The live-steam valve is gradually opened. The portions of the apparatus in which the juice is boiled, and those in which the steam circulates, should be thoroughly tested before the campaign commences. The pressure to which they are submitted must be twice that under which they are to be subsequently worked, and there should be suitable gauges, etc., such as are used on the compartments of the effect. Precaution must be taken by sampling the juice from the fore-evaporator, because a certain pressure prevails in the apparatus which projects the juice with considerable force when any communication is made with the exterior.

The consumption and production of vapor in the fore-evaporator are extremely variable, much more than in a multiple effect; for it connects with many of the heating stations, in which the consumption is likewise very variable. It is especially high when a new strike in a pan is about to commence, for then a considerable portion of the water from the thick syrup must be evaporated in a relatively short time. On the other hand, when the graining is nearly completed, live steam is used and the fore-evaporator is not called upon for its caloric.

It may occur also that all the exhaust vapors from the machines of the factory cannot be utilized in the first compartment of the multiple effect, owing to a temporary stoppage, and during this interval the fore-evaporator is consuming a considerable volume of

steam taken from the boiler, while the non-utilized exhaust steam is escaping into the air. To avoid this, CLAASSEN proposes that a suitable valve connect the exhaust-steam pipes with the vapor pipe of the fore-evaporator, this valve to be kept always open during the working. Under these conditions, there is a common pipe for exhaust-steam and the vapors of evaporation, from which diverge all the ramifications connecting with the reheaters and the vacuum pan. In the fore-evaporator there exists, then, the same pressure as in the exhaust collector. The entrance of the heating vapors into the special evaporator may thus be very simply regulated, and the pressure kept at any degree desired. Thus, the vapor is utilized under the best possible conditions, and the general working is very greatly simplified, with no apprehension regarding excessive frothing in the fore-evaporator, when for a short period it has to yield a considerable volume of vapor.

It is sometimes very difficult to regulate the pressure in the fore-evaporator. With but little inattention on the part of the person in charge, this pressure may become very considerable, especially if the demand for the vapors of the apparatus should be suddenly lessened. According to MALANDER, the juice chambers should have suitable safety valves which permit the vapor to escape outside of the factory as soon as their pressure exceeds one-half an atmosphere, the average pressure admitted, for an explosion can result when the fore-evaporator is not cared for. A case in point is where the pan-man opens at the same time the live-steam and vapor valves; the pressure will rise and one may cut off the live steam entering the fore-evaporator: it will be ineffective. The purgers for condensed water should also have safety-valve attachments.

In the foregoing, several examples were given of automatic valves for the admission of steam. These are used mainly on the fore-evaporator. When this fore-evaporator is connected with the exhaust-steam pipe, the installation for regulating the arrival of the steam from the boilers, which is influenced by the pressure in the boiling chamber, may be in a measure desirable, but is not essential, as sudden variations of pressure seldom occur, and the workman in charge need only watch the exhaust-steam pressure gauge.

Another fact, not previously mentioned, which prohibits the maintainance of excessive pressure in the fore-evaporator and the first compartment of the effect, is the decomposition of sugar; but

these transformations are very little to be dreaded up to the limit of 115° C. The danger of this decomposition is very great if a two-atmosphere pressure is adopted, as is customary in some sugar factories, for then the corresponding temperature is 134° C. Most of the principles which govern the management of the LEXA-RILLIEUX mode have been described in the foregoing pages.

CHAPTER VIII.

PERTURBATIONS.

Frothing.—The perturbations which may occur during the working of a multiple effect are more numerous than is generally supposed. Evidently excessive frothing in all the compartments is of frequent occurrence. By the modern modes of working the level of the juice is kept very low in the tubular cluster, and the dangers of the froth being carried by entraînement into the next compartment is thus lessened, especially when the evaporating chamber is exceptionally high. In the older, high-level modes of working, entraînement existed and the catch-all could not prevent it. The froth combined with the condensed water in the next compartment of the series and found its way into the boilers, causing considerable loss and trouble. Such waters cannot be used in diffusion batteries, as the waste water from the battery would then contain more sugar than usual, and more sugar would be lost on that account. Various modes have been suggested by which to overcome the difficulty, but none of them has given satisfactory results.

Frothing may be due to overfilling the compartment with juice. In no case should the end of the tubes be seen when looked at through the peep holes. This frothing tendency depends also upon the beets worked, their condition of maturity, and whether the carbonatation has been poorly effected. The difficulty may in a measure be kept under control by watching the alkalinity. Considerable frothing occurs in the fore-evaporator when there is a sudden removal of vapors. In the rush to force the efficiency of the multiple effect, the frothing is always excessive. When, for one reason or another, more than the usual quantity of vapor is drawn from the multiple effect, the frothing is very abundant. The pan man is frequently responsible for frothing in the multiple effect or in the fore-evaporator when the pan is suddenly started, a practice

which should never be encouraged. This frothing is most noticeable in the first compartment when working according to the LEXA-RILLIEUX mode, or in the fore-evaporator when working by the PAULY-GREINER method. The best froth arrestor in such cases is a slight reduction in the vacuum by introducing a small volume of air by the butter cock, or by running some special fatty substance into the pan through it. This mode should be used only in exceptional cases, as it influences the quality of the juice, rendering difficult the subsequent filtration of the syrups, and soiling the tubes with which it comes in contact. The best oils for this purpose are cocoa butter, castor oil, etc. Under all circumstances the water collected in the sugar arrestor should be frequently examined, so as to make sure that they contain no sugar.

Leakages.—Another cause of sugar losses is leakage of the tubes, but during the normal working of the multiple effect very little loss from this source can occur, as the pressure of the vapor used for heating is always higher than that in the chamber where the boiling occurs, including the pressure of the column of juice. At joints that are not sufficiently tight condensed water and vapor can enter the juice, but the reverse is never the case—the juice cannot find its way into the heating chambers. However, in special instances of perturbation, the conditions of pressure may be completely changed, and losses of juice are then the natural outcome of such leakages.

It may be said that the leakages in the evaporating chamber never reach very alarming proportions, provided the ammoniacal water is entirely drawn off, otherwise the ends of the brass tubes when they come in contact with the tube plates would be eaten away after a time. One should watch very carefully the condition of the heating tubes to make sure that their joints with the tubular disk are in a good condition. Before the sugar campaign commences, the multiple effect, after being placed in first-class condition, should be tested under water pressure, obtained by a water reservoir placed at an elevation giving a pressure of at least one atmosphere. In vertical multiple effects the pressure is exerted inside of the calandria; with the horizontal type it is on the side of the boiling chamber. Under these circumstances the tightness of each of the tubes may be ascertained.

As soon as a leak is discovered it is important to make the necessary repairs without delay. A great mistake is frequently made by plugging both ends of the faulty tube, for, as a general thing

when one tube is attacked, most of the other tubes are in the same condition; therefore, it is better to remove the tubes entirely and replace them by fresh ones. After the sugar compaign all the tubes that have a reduced thickness should be replaced.

Advantages and disadvantages of frothing.—The juice sometimes shows evidence of excessive frothing, when the conditions of pressure vary for one reason or another. Frothing within reasonable limits may be advantageous to a satisfactory evaporation of juice at a low level in the apparatus, but, on the other hand, if the frothing is excessive the heating surfaces are not sufficiently moistened. All dry portions are necessarily inactive, which explains why the pressure in the heating chamber increases during abnormal frothing.

Sugar losses.—It has already been pointed out that there need be no fear of serious sugar losses by decomposition in the multiple effect, provided the highest temperature attained does not exceed 115° to 120° C., and the juices remain alkaline. No one can deny that small sugar losses do occur, which, however, under normal conditions, are not more than a fraction of a per cent.

BATTUT [1] from a series of arguments concludes that the losses of alkalinity during evaporation are due to certain fermentations, during which there is sugar inversion. More modern experiments and observations refute this idea, and if such losses occur, it is only under very exceptional circumstances. According to HORSIN-DÉON,[2] the dark coloration noticeable when juices are submitted to exceptionally high temperatures in the multiple effect is due to the decomposition of foreign, organic substances, and not to sugar destruction.

The KASPAR [3] arguments are of special interest. According to them sugar when hot undergoes the following decomposition: Through continued boiling at 100° C. there is an inversion depending upon the dilution. At 150° C. this inversion is much more rapid and the boiling, if continued at that temperature, will result in the formation of furfurol. At 160° sugar carbonizes with formation of humic substances, levulic acid, formic acid, etc. In an alkaline solution there are formed fumic, glucic, and saccharic salts. On the other hand, when the solutions are acid, which frequently occurs when sugar enters the boilers, there is formed apoglucic acid.

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[1] Bull. Ass., 10, 139, 1892. [2] *Ibid.*, 10, 469, 1892.
[3] Oe.-U. Z., 17, 661, 1888.

Under certain special conditions there are found oxalic and glycolic acids.

According to WEISBERG,[1] the influence of high temperature is in direct ratio to the concentration of the juice. SYDERSKY[2] estimates the losses caused by the destruction of sugar during evaporation and graining, by determining the saline coefficient before and after these operations. The result obtained by this expert corresponds to 0.18 per cent of the weight of the beets sliced. On the other hand, BATTUT[3] claims that the destruction through heat during evaporation is 0.09 per cent of sugar, estimated upon the weight of beets sliced. The most interesting investigations relating to sugar losses during evaporation are those of HERZFELD.[4]

CLAASSEN points out that these sugar losses increase, not only with the temperature, but with the period during which they are submitted to the heat. For 100 parts of sugar there will be destroyed in an hour at 100°, 0.114 parts; at 110°, 0.163; and at 115°, 0.175. Consequently, if the juice is evaporated in the multiple effect for a period lasting thirty minutes at 115°, and in another apparatus for a period of an hour at 100°, there would be a greater loss in the latter case than in the former.

The same authority gives practical examples of the data given by HERZFELD.[5] His calculations are made under the following conditions:

SUGAR LOSSES IN A MULTIPLE EFFECT.

Kind of apparatus used.	Time the juice remained in apparatus.	Sugar losses.	
		Sugar.	Beets.
	Minutes.	Per cent.	Per cent.
(A) Quadruple effect working under high pressure	54	1.0497	0.0065
(B) Quadruple effect working under low pressure	79	0.0487	0.0063
Triple effect with fore-evaporator	57	0.0711	0.0092

The evaporation of juice in a multiple effect takes a considerable time when the capacity of the apparatus is too great for the volume of juice being handled, or when the evaporation is effected with comparatively slight falls in temperature.

TOLPIGUINE[6] calls attention to a fact based upon rational and

[1] Bull. Ass., 10, 518, 1893.
[2] *Ibid.*, 5, 413, 1887.
[3] *Ibid.*, 10, 152, 1892.
[4] Z., 43, 745, 1893.
[5] B. Z., 18, 145, 1893.
[6] Bull. Ass., 16, 971, 1893.

practical observations. It is that the losses are in direct proportion to the heating surfaces. He gives the practical yields in white sugar of five Russian factories, in which the total weight of beets sliced varied greatly. These observations were continued during a period of several campaigns, viz., 1889, 1890, and 1891. The proportions for the heating surfaces are calculated in square feet for 10 puds [1] of beets sliced. The yield of white sugar is calculated upon a basis of 100 parts of sugar as determined by analysis in the beets.

RELATION BETWEEN HEATING SURFACE AND SUGAR LOSSES (TOLPIGUINE).

Campaign.	Bielokolodets.		Kochanka.		Moguilna.		Losny.		Tourbow.	
	Proportional surface.	Sugar yields.	Proportional surface.	Sugar yields.	Proportional surface.	Sugar yields.	Proportional surface.	Sugar yields.	Proportional surface.	Sugar yields.
1889–90	5.76	70.90	3.90	77.32	3.91	73.31	3.79	73.00	4.28	74.32
1890–91	7.78	63.59	4.28	73.64	5.57	69.29	4.77	71.60	6.24	69.71
1891–92	7.04	67.46	4.22	75.00	4.75	76.96	5.72	67.89	5.76	69.53

The space occupied by the juice is greater than is needed when it is evaporated at a high level, or when there is too much space beneath the tubular cluster in the vertical appliances, or between the tubes in the horizontal apparatus. For this reason, as explained under another caption, it is desirable to evaporate at a low level, and the multiple effects should be built in such a way as to reduce the dead space to such proportions as will just permit a satisfactory circulation of juice. One should also avoid the practice of drawing into the multiple effect an amount of juice that would cover the tube plate. When the compartments contain considerable juice, or when the concentrated juice or syrup cannot be removed with sufficient rapidity, the efficiency of the multiple effect is diminished at a moment when it should be increased.

All perturbations in the working naturally tend to prolong the period necessary for evaporation, and this of course means an increase in the chances of sugar loss. The boiling point should never exceed 120° C., at least not for any length of time, as the sugar inversion beyond that limit increases for each degree. This temperature corresponds to a pressure of one atmosphere. In case one is obliged to evaporate neutral or slightly acid juices (which mode

[1] The Russian foot = 30.48 cm., the Russian pud = 16.48 kilos.

of working is not to be recommended), the boiling temperature should never exceed 100°, and even then serious risks are incurred. Under these circumstances it is impossible to utilize steam economically.

Syrup pumps.—There is evidently an important relation between the efficiency of a multiple effect and the syrup pumps. When these are out of order the general working of the whole apparatus is interrupted, and finally ceases entirely, as a result of the accumulation of juice in the apparatus. It is then impossible to continue the evaporation without soon attaining an excessive concentration which may be followed by crystallization and stoppage of the exit pipes. The best remedy in this case is to close the juice valve leading into the last compartment and introduce water, which, however, results necessarily in lowering the purity of the juice. During this interval the exit pipe of this compartment should be thoroughly cleaned. In order that these pipes may be readily removed there seems to be advantage in having an interchangeable suction pipe placed close to the last compartment.

Cleaning of the pipes.—To clean [1] the bent pipes it is proposed that rods be used consisting of spiral steel wires, to which brushes of different diameters may be attached. The arrangement is such that all parts of the pipes are successively cleaned.

Catch-all clogging.—Even in the return pipe from the last sugar arrestors or the catch-all of pan there may be obstructions of more of less importance. In order that the difficulty may be overcome, it is necessary to disconnect these pipes. This can be done without stopping the multiple effect if it is done quickly. Two plugs are put one in the catch-all and the other in the compartment instead of the disconnected pipe. When the pipe is cleaned it should be put quickly in its former position. In the case of the vacuum pan the difficulty is even less. Upon general principles, when these pipes are clogged by rust, etc., serious sugar losses are apt to follow.

Stoppage in boiling.—For one reason or another, the boiling of the juice in one of the compartments may cease. It may be the fault of the evaporating man, who has kept the same vacuum in two of the directly connected compartments. Under these circumstances the juice will not pass from the one to the other. Experience shows that this difficulty may be largely overcome by

[1] D. Z. I., 24, 1360, 1899.

having the compartments communicate at the bottom, by which means the juice readily circulates, even when there exists but a very small difference of pressure between two compartments. The conditions of satisfactory working can be reëstablished by producing the requisite vacuum in each section by closing the faulty ammoniacal purging cock. The vacuum falls in one of the compartments when there is an accumulation of water or ammoniacal vapors in the section that follows, and the equilibrium is then established through the ammoniacal water purgers. As water frequently accumulates, and may not be discovered at once, it shows the desirability of having water-level attachments on each compartment.

Abnormal pressures.—In the heating clusters of the fore-evaporator and the vacuum pan, or in reheaters in which live steam is used for heating, unusual pressures may exist, owing to the accumulation of water which is nearly always due to some faulty working of the purger, to the sticking of the valve, or to the inefficiency of the float. The latter should always have a rod attachment by which the valve may be raised from the exterior and an exit flow thus created. An objectionable feature of this method is that the men in charge frequently plug the rod in position, so that the valve remains continuously open, thus causing a considerable loss of steam.

Faulty working of the pumps.—It frequently happens that the vacuum in the compartments is excessive, resulting in the sticking of the pump valves to their seats, and this continues even when the vacuum decreases. Characteristic sounds of the valve's working are a sure indication of the condition of affairs. The only remedy is to take the pump apart. There is a practical way, however, of overcoming the difficulty which consists in having a pipe communication between the upper part of the valves and the condenser. The higher vacuum of the latter sucks open the valve and the normal conditions will then prevail. This plan is not practicable in all cases, especially when the pump is handling condensed water from the reheater placed between the last compartment of a multiple effect and the condenser; but, as the reheater is generally at a certain elevation, the water collected in the pipe compensates for the prevailing vacuum in the reheater.

Low vacuum.—At the opening of a sugar campaign, it frequently happens that there is a low vacuum in the last compartment and consequently a high pressure in those that precede, owing to leakage

of the joints in the apparatus working under vacuo and in the pipes conducting the vapor of evaporation. The air which enters in this manner paralyzes the condensation of the vapor in the condenser and surcharges the air pumps. When the leakages cannot be detected by the noise made by the air entering into the apparatus, they should be located by the flame of a candle, and closed up with suitable cement.

Indications of perturbations.—The variations in vacuo and pressure in the compartments determined by experience will show perturbations in the general working of a multiple effect, and these fluctuations are always followed by a decreased efficiency of the apparatus, considered as a whole.

Calcareous deposits.—If these variations manifest themselves little by little toward the end of the week, in such a manner as not to influence the vacuo in the concentrated juice compartment, and to increase the pressures in the preceding compartments, this is an indication that there has been a calcareous deposit upon the heating tubes

These deposits, as previously explained, always lessen the efficiency of the multiple effect, due to decreased conductibility of the tubes and steam condensation. The only remedy is to keep the juices at the most desirable alkalinity, so that there will be a minimum of calcareous deposits. Whatever the conditions the apparatus should be repeatedly cleaned. This is generally done on Sundays in countries where the laws demand a complete stoppage of the factory.

CHAPTER XI.

STOPPAGE AND CLEANING OF A MULTIPLE EFFECT.

Upon the tubes of an evaporating appliance there are certain incrustations which consist of carbonates, phosphates, silicates, sulphates, aluminates, oxalates, and certain calcic organic salts. The carbonates and organic lime salts are porous in their texture, offering only a limited resistance to the passage of heat, and are readily removed. On the other hand, the sulphates and phosphates are very bad conductors, and are most difficult to remove from the surface of the tubes; when only one millimeter in thickness they can destroy the evaporating capacity of the apparatus.

The composition of these incrustations, as given by GAWALOWSKI[1] is: Calcium oxalate, 58.61 per cent; calcium sulphate, 0.71 per cent; water, 11.7 per cent; ferric oxid, alumina, and other mineral substances 7.40 per cent, and organic substances, 22.38 per cent. Numerous efforts have been made to prevent the formation of these incrustations, rather than to remove them after they have been deposited. To remove the precipitates formed in the juices PIEDBOEUF proposed that special filtering devices be placed between the compartments. For this purpose PHILIPPE and CLARITAS filters have been used. The filtering cloths should be carefully selected, so as not to retard the filtration under these circumstances. Of late sand filters have been proposed also. BOUVIER's device has in view the prevention of the deposits on the tubes of multiple effects, and gives them an opportunity to deposit upon iron filings. These should be first dipped into milk of lime, which adhering to the small particles of iron forms a centre for the crystallization of calcic salts. After the iron scales have done their work, they may be withdrawn and replaced. It has also been proposed to introduce into the apparatus alloys of granulated aluminum.

Mechanical devices for preventing these deposits have met with

[1] D. Z. I., 4, 278, 1879.

more or less success. Among them the NOVAK[1] chain device (Figs. 112 and 113) may be mentioned. These chains were hung in the interior of the vertical tubes. In one case (Fig. 113) the springs, *E*, are fastened to the upper dome, *F*, of the compartments; beneath the springs is a series of chains, *B*, which hang down into the tubes, *C*. During the passage of the juice the automatic scraping of the chains against the sides of the tubes prevents any deposits. The arrangement shown in Fig. 112 has the same purpose in view, but instead of springs the chains, *B*, are suspended to *D*,

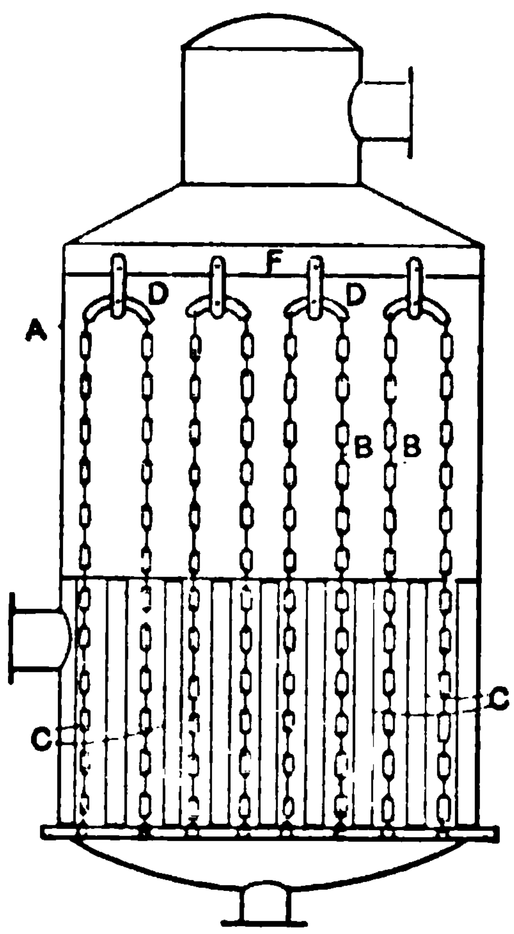

FIG. 112.

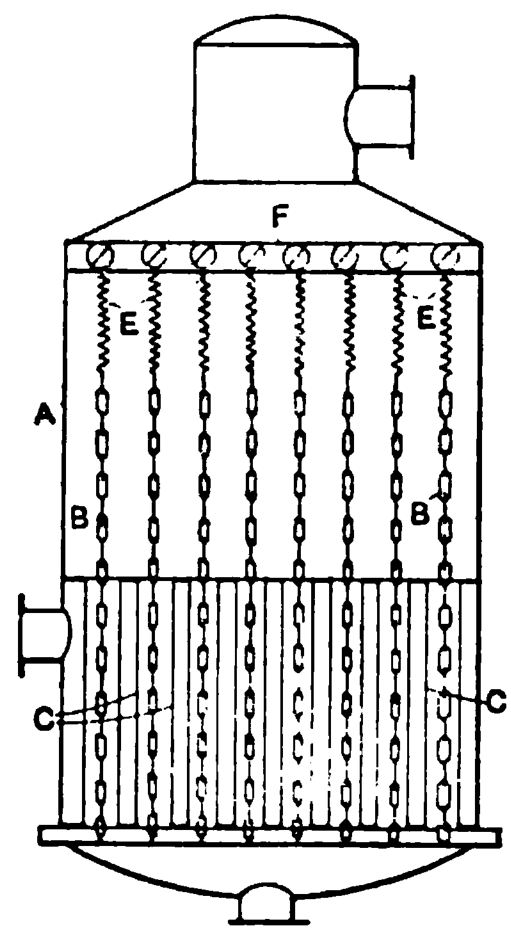

FIG. 113.

NOVAK'S Chain Device for Cleaning the Evaporators.

which consists of two arms. The velocity of the liquid in the tubes not being exactly the same, there will result a motion producing the same results as the spring combination of Fig. 113.

LAGRELLE and CHANTRELLE (Fig. 114), on the other hand, proposed and adopted with more or less success a scheme which consisted in suspending in the interior of the tube, *a*, a hollow stick, *b*, of a density nearly the same as the liquid contained in the apparatus. These sticks float in the juice being concentrated and

[1] S. B., Oct. 1898.

cannot escape from the tubes owing to the stoppages g, g^1, g^2. On the exterior of these sticks there is an elongated spiral, d, which causes them to rotate in the interior of the tube. The surface being thus constantly scraped no deposits can form. Very few of these devices have ever made much of a practical success.

Stoppage.—Evaporating appliances in order to be properly cleaned must be emptied, for which purpose the working must be stopped, or the stoppage may be necessitated by an accident. Sometimes the situation is such as to prevent the use of the regular methods of bringing the multiple effects to a standstill. In most cases this is done in the following manner:

After the last portions of the filtered juice have been drawn into the apparatus, the evaporation continues for a reasonable time, after which the suction from the first compartment is made into the second. This is accomplished under certain difficulties.

MALANDER recommends that the juice pipes connecting the different compartments be very low, so that the emptying will be complete in the compartments. To accomplish this under satisfactory conditions, the difference of pressure between the two compartments should be as great as possible, by which means rapidity of circulation is increased. Experience shows that in most cases it is then difficult to obtain a notable difference of vacuo, as at that time there exists considerable vacuum in the first compartment. In order to reduce the vacuum in this case air may be introduced through the butter cup, taking the precaution to close the exit ammoniacal cock of the second compartment. To follow the conditions of circulation from the outside one need only listen to the sounds made by the valves of communication. After a certain time the noise will indicate that a mixture of water and air passes the valve and that the compartment is empty.

FIG. 114.—LAGRELLE and CHANTRELLE Tube-cleaner.

Washing.—The water valve connected with each compartment is left open. There follows a preliminary washing and the circulation continues to the second compartment. After a reasonable interval the valve of communication between the compartments is closed and the compartments are filled with water, so that the

tubular cluster or calandria is entirely covered. Under these conditions very little sugar will remain in the apparatus. In the LILLIE evaporator the washing is conducted under excellent conditions, and may be accomplished in less than thirty minutes. This rapidity, as compared with that of other methods, is explained by the comparatively small quantity of sugar remaining in the apparatus after it has been emptied; furthermore, there is not the great dilution of juices that frequently occurs in the standard multiple effects after a thorough washing. A LILLIE apparatus, evaporating 700 hl. of juice in 24 hours, will not give more than 7 hl. of washing water at 7° Bé.

Removal of deposits.—The mechanical removal of the lime deposits during the campaign, by brushing, scraping, etc., is accomplished in the vertical appliances, but cannot be properly done in the horizontal multiple effects, for the reason that the pipes must be displaced from their position for the cleaning. But even in the vertical evaporators the mechanical mode of cleaning is difficult, demands considerable time, and is necessarily an unpleasant operation for the workmen, so in most cases preference is given to the chemical method of removing deposits by solutions of boiling soda, diluted hydrochloric acid, etc. Even when applied once a week, this method is sufficiently satisfactory to permit the working of the multiple effect during the entire campaign.

ROD[1] recommends that multiple effects be emptied and that steam at 100° to 110° C. be introduced into the heating chamber. The incrustations on the pipes will separate, owing to the expansion of the tubes. This idea may be a good one, but its practical applications have been few. SCHREIBER[2] proposes to have movable tubes in the calandria, so that they may be taken off, cleaned, and replaced in position on the tubular plates.

If the deposit consists almost entirely of carbonate of lime, it may be removed with a diluted solution of hydrochloric acid; but as it frequently contains many other calcic salts, such as calcic soaps, the outcome of fats added to allay frothing, their solution offers difficulties, for these fatty mineral substances are not acted upon by hydrochloric-acid solutions or other solvents. It is to be noted, however, that the mineral fats under consideration are seldom used in the compartments of a multiple effect. There often remain on the surface of the tubes particles of fatty substances

[1] Oe-U. Z., 24, 86, 1895.

[2] S. I., 5, 45, 1870.

that have not been saponified, and the acid solutions will then not come in contact with the tubes, in cleaning by the regular methods.

In all these cases it is desirable to use weak solutions of soda to transform the calcic salts into carbonate of lime. The soda dissolves the non-decomposed fatty substances and tends to break up the incrustation, which, thus transformed, is readily dissolved by hydrochloric acid. It is only in very exceptional cases, usually when considerable silica and alumina are present, that the deposit will resist this chemical treatment. The hydrochloric acid used should not be too concentrated, as it would dissolve the iron of the sides of the apparatus and thus weaken them. CLAASSEN advises to use in the last compartment containing the thickest deposits a solution containing not more than one per cent of pure acid, and in the other compartments it should never be more than 0.25 to 0.5 per cent. To introduce the chemical solutions for removing the incrustations into the multiple effect without opening the apparatus special pipes may be added to the compartments.

CLAASSEN says that to prevent the sides of the apparatus from being attacked by the suction of the concentrated hydrochloric acid, which might remain at the point of aspiration for a few instants, it is advisable to boil the water under vacuo and introduce the acid (through a pipe ending in the middle of the apparatus) at a moment when the water boils, by the motion of which the mixture obtained is satisfactory. The boiling should not last too long, say not more than an hour, and only a moderately high temperature should be maintained. If this rule is carried out the efficiency of the multiple effect is restored and the strength of the apparatus does not change, giving satisfactory results for many years. The condensed water obtained when boiling with acid should be tested as to its acidity. If acid the condensed water cannot be used in the boilers unless neutralized with soda.

The sodic solution used for cleaning by boiling should contain from 0.5 to 1.5 per cent of carbonate of soda. The boiling with this solution in all the compartments should last as long as possible and at a comparatively high temperature. The vacuo should be considerably reduced by closing the valves through which the vapors of evaporation pass, or by injecting very little water into the condenser. To accomplish the removal of deposits a moderate boiling is sufficient.

STRAUB[1] recommends that each compartment be submitted to

[1] Archief., 2, 692, 1894.

separate open-air boiling at 100° C., by opening the manhole communicating with the juice chamber. At the bottom of each compartment there are special steam distributors. Horsin-Déon[1] recommends boiling with an acid to remove a portion of the lime combined with the silica, this to be followed by a caustic-soda treatment and in some exceptional cases a second boiling with hydrochloric acid. The final silica deposits are removed as a powder by scraping, followed by a new alkaline and acid washing. When the multiple effects are submitted to regular boiling, the following precautions should be taken in rinsing.

The exhaust-steam valve and the valve connecting the multiple effect with the condenser are closed, air is allowed to enter the compartment through the butter cups, and the apparatus is emptied through the exit cock. Before entering one of the compartments, it is desirable that it be thoroughly cooled. This is accomplished by creating a circulation of air through the manholes above and beneath the tubular clusters. The water valve is open in full.

All the pipes used for the washing of the multiple effect should centre on one distributing pipe, which may be closed by a suitable valve arranged so as to be locked during the regular working of the evaporator, under which circumstances no water can be added to the juices during their concentration. One cannot examine a multiple effect after this acid washing, until all the air contained in its interior has been removed, as there would be danger of an explosion.

If, after the washing, the normal efficiency of the apparatus is not restored, this indicates that the acid solutions used were not sufficiently strong, or that the boiling did not last long enough to produce the desired effect, and the operation should be more thoroughly conducted on the following Sunday. It is not absolutely necessary that the heating tubes be shiny and entirely free from all deposits, as the efficiency of the multiple effect becomes almost normal when the calcareous deposits are broken up and reduced in thickness.

The great advantage of the Lillie evaporators over most of the multiple effects in use is that they need no acid for their cleaning—instead the incrustations are removed by circulating the juice in alternate directions. It is said that the results obtained with cane

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[1] Horsin-Déon, Traité II, 2, 665, 1901.

juices are most satisfactory, but no data as to the success with beet juice, which leave much heavier deposits than the former, have been found.

Mechanical cleaning.—However, in most cases it is necessary to clean the tubes by some mechanical means. This always necessitates the men entering the apparatus, which should be cooled and ventilated as mentioned in the foregoing, and, notwithstanding these precautionary measures, the men must come out as soon as they feel any ill effects. The cleaning is done with long wire brushes, one or two up-and-down movements being sufficient to remove all the adhering deposits. In horizontal evaporators the cleaning demands that the pipes be removed, as the deposits are upon their exterior surface. In some German factories [1] a very simple method for this exterior cleaning consists in placing the tubes in a rotating drum and giving it a rotary motion, which may be accomplished by hand or by mechanical means. A certain quantity of sand or acid placed in the interior hastens the operation. Attention has already been called to the importance of keeping the exterior of a multiple effect in a thoroughly clean condition. This necessitates the repeated polishing of all the metal attachments and the painting and varnishing of the laggings. All the moving parts of the valves, etc., accessible from the outside should be kept in perfect order, and the peep-hole glasses should be cleansed from any interior deposits.

[1] Z., 51, 859, and 860, 1901.

CHAPTER X.

CALCULATIONS RELATING TO THE EFFICIENCY AND HEATING SURFACE OF THE MULTIPLE EFFECTS.

General remarks.—The treatment of the subject of evaporation would not be complete unless a certain amount of data were given showing upon what reasoning the calculations for the appliances used have been made. The subject is a delicate one and belongs to the realm of specialists who do not agree either in their arguments or methods of calculations. Rather than introduce long and very complicated theories, as advanced by certain mathematicians who frequently have had very little practical experiences, it seems preferable to confine the examples given to two leading French experts and a German authority. The reader may appreciate for himself how difficult it is to draw any exact conclusion.

Volume of juice to be evaporated.—Before beginning the calculations it is important to keep in mind the volume of juice to be evaporated. This necessarily differs from factory to factory and depends upon the method of beet-sugar extraction, that is to say, the mode of handling the diffusion battery, defecation, filter presses, etc. In the now obsolete method, used formerly in the Austrian beet-sugar factories, the volume of juice to be handled was frequently 200 per cent of the weight of beets sliced. In DESSIN's calculations it is supposed that this volume is 148.2 per cent of the weight of the beets. HORSIN-DÉON bases his calculations on about 140 per cent, while CLAASSEN does not allow for more than 120 per cent. The greater the volume of water to be evaporated from a juice with the view to its concentration the higher will be the cost of fuel to bring about this result, and the main object in a well-organized sugar plant is to extract the maximum sugar from a given weight of beets with the minimum expenditure of fuel. When the volume of juice to be evaporated and the volume of vapor to be drawn off for the pan and reheaters are known, the calculation

of the total heating surface offers no difficulty. In the calculations that follow no allowance has been made for the caloric lost from the appliances and pipes through radiation. HORSIN-DÉON makes allowance for the specific heat of the juices. DESSIN and CLAASSEN, on the other hand, appear to hold this factor too insignificant to be considered when estimating steam consumption.

Fall of temperature.—DESSIN argues that one should estimate the requisite heating surface by the fall of temperature that is determined in advance; on the other hand, most of the evaporating experts and machine builders maintain that this fall of temperature regulates itself, so that the apparatus always yields when working a maximum efficiency with the proper regulation of steam and vacuum. The DESSIN calculations refer to vertical triple effects, such as are generally used in Continental Europe.

It may be admitted that the tension or absolute pressure of the exhaust steam from the various machines in the exhaust-steam collector is 1.5 to 1.55 kilos, which supposes for these vapors a temperature of 112° C. It may also be supposed that the vacuum in the third compartment of the multiple effect is 58.5 cm., which corresponds to an absolute tension of 17.5 cm., or more correctly speaking to 0.184 kilos absolute pressure. The vapors at that tension are at 58° C. If considered separately each compartment of a triple effect is a simple effect, in which the requisite heat for the vaporization of one kilogram of water is about equal to the quantity of heat abandoned by one kilogram of condensed steam in the tubular cluster or calandria. With the exception of the first compartment, which supplies the steam to be used for reheating the juices, the volume of water evaporated in each of the compartments of a triple effect is nearly the same. The surface with which the juice comes in contact is about the same in each compartment, and according to DESSIN the fall of temperature in each case should be more or less equivalent.[1]

[1] In the experiments of HORSIN-DÉON it was shown that the condensation per square meter of a heating surface S, per degree and per hour, for a fall of temperature c, and a variable volume of water e, was as follows:

$$\frac{e}{Sc} = \begin{cases} \text{First compartment (triple effect)} \ldots\ldots\ldots\ldots = 3.84 \text{ kilos} \\ \text{Second compartment (triple effect)} \ldots\ldots\ldots = 2.85 \text{ kilos} \\ \text{Third compartment (triple effect)} \ldots\ldots\ldots\ldots = 1.89 \text{ kilos} \end{cases}$$

The falls of temperature were 9.08° C. in the first compartment, 12.08° C. in the second, and 18° C. in the third. In other words, the falls of temperature were inversely proportional to the quantity of water condensed per unity of surface and time for 1° C. (HORSIN-DÉON, 11, 1530, 1900).

He considers the fall of temperature not as the difference shown by the recording instruments, but as the difference between the temperatures of the vapor in the tubular cluster of one compartment and that of the boiling juice in the tubular portion of the same compartment. In accordance with previously admitted data, this fall of temperature should be

$$\frac{112-58}{3}=18^\circ \text{C.},$$

but in most of the existing appliances, and with the methods of operation, it is practically impossible to attain such limits. This point may be actually determined, and the argument that follows will show just why the limit of 18° C. cannot be realized. He admits for the sake of argument that the juices to be concentrated should be reduced from 5° to 25° Bé., or from 9° to 45.83° Brix. As previously pointed out, the evaporation is about the same in each compartment, and it is possible to determine the degrees of concentration of the juice in its passage from one compartment to another, especially when the multiple effect is working continuously. Approximately, the following conditions exist:

Waiting tank...........	9° Brix.............	Density, 1.036
First compartment.......	12.03° Brix..........	Density, 1.049
Second compartment.....	19.6° Brix..........	Density, 1.080
Third compartment......	45.83° Brix...........	Density, 1.219

The densities are supposed at 15° C. As these data have an important influence on the determination of fall of temperature, it is important to make certain corrections upon a basis of the existing temperatures in each compartment. For the present it may be supposed these are 99°, 85°, and 68° C. respectively in the three compartments, and that the actual densities of the juice during evaporation are as follows:

First compartment..........................	Density, 1.008
Second compartment.........................	Density, 1.054
Third compartment..........................	Density, 1.185

It is interesting to examine the method by which the boiling of the juice in a triple effect with tubes 1.5 meters in length is effected. When a triple effect is conducted according to the old rules, the level of the juice to be evaporated is a few centimeters above the bottom of the front observation lenses, the level of the boiling

liquid[1] being about 0.230 meters above the tube plates. But in order that the vapor formed in the tubular cluster of one compartment may escape from the liquid it should be at a tension equal to the vapor contained in the portion where the boiling is effected, increased by that which is necessary to raise the liquid mass. This supplementary tension consequently varies with the tubular cluster in which the vapor is formed. For the vapor produced at the lower portion, the maximum height of the mass to be raised is

$$1.5 \text{ m.} + 0.230 \text{ m.} = 1.730 \text{ m.}$$

On the other hand, for the upper portion the height is at a minimum of 0.230. In the present argument only the middle portion of the tubular cluster is considered. Consequently the distance to the juice level is

$$0.750 \text{ m.} + 0.230 \text{ m.} = 0.980 \text{ m.}$$

This means an average between the maximum and minimum heights as above determined. As the vapor at the period when it is produced in the tubular cluster is at a greater tension than that which is already liberated from the juice, it is necessarily at a higher temperature than the latter; and while the temperature of a boiling liquid is equal to that of the vapor at the time of its production, he admits that the average temperature of the boiling juice in the tubular cluster is higher than the vapor in the boiling chamber of this same juice. This excess of temperature is equal to the difference of temperature of steam at the time of its formation and after it has been liberated from the liquid. It must be noted that the liquid mass to be raised consists of the juice contained in the compartment, which is emulsioned by the vapor already produced, and that which escapes through the mass. The emulsion has evidently a tendency to diminish the density of the liquid.

The third compartment of a triple effect may now be considered, in which the vacuum is 17.5 cm. (0.184 kilo absolute pressure). The compartment has an interior diameter of 1.820 m., and contains 630 tubes 1.5 m. long with an interior diameter of 46 mm. The total volume of juice to be considered, supposing that the multiple effect is not working, consists of the volume in the

[1] Under another caption it was shown that the best mode, as now adopted, consists in having the juice only one-third the height of the tubes.

interior of the tubes and the volume of juice above the tubular plate to a height of 0.230 m., less a certain depression for the emulsion, representing 0.150 m. (It becomes necessary to make allowance for the bottom where no emulsion is produced during boiling.)

This volume of juice at rest is made up as follows:

		Liters.
Juice	In the tubes	1575
	Above plates	390
	Total	1965

The volume of the mass during boiling is the same increased by the depression.

	Liters.
First volume of the juice at rest	1965
Second volume of the depression	208
	2173

No allowance must be made for the weight of the vapor which occupies the volume where the depression is created. (The vapor in this special case weighs only 0.160 to 0.190 kilo the cubic met r.) It may be concluded that the density of the boiling mass and that of the liquid at rest are inversely proportional to the volumes above determined. As already pointed out, the density of the juice in the third compartment is 1.185, and that of the boiling mass in the same compartment will be

$$\frac{1.185\times 1965}{2173}=1.071.$$

The resulting vapor in the interior of the tubular cluster and at the middle of the tubes will have to raise a mass 0.980 m. in height, the density of which is 1.071. It should have, over the vapor contained in the receptacle, an excess of tension corresponding to a column of water $0.980\times 1.071=1.050$ m., which represents a pressure of 0.105 kilo. The absolute tension at the time of its formation should consequently be $0.184\times 0.105=0.289$ kilo. The corresponding temperature at that pressure is 68° C. and the vapor in the interior of the receptacle is at 58° C., or a difference of 10° C. Consequently the average difference between the boiling temperature of the juice in the third compartment of a triple effect and that of the vapor is 10° C. Applying the same argument to the two other compartments of the multiple effect, it is found that this difference is 4.5° C. for the second compartment and 2° C. for the first.

From the foregoing it follows that the fall of temperatures in each of the compartments under the supposed circumstances will be

$$\frac{112-58-(10+4.5+2)}{3}=12.5° \text{ C.}$$

But, as there is a flow of the vapor of one compartment to the calandria of the following one, there necessarily is a difference of pressure in these two portions, and this means a difference of temperature. DESSIN supposes for the latter 0.5° C. The actual fall of temperature is consequently 12° C.; and the working conditions of a triple effect, with compartments of same size, may be summarized as follows:

	First compartment.	Second compartment.	Third compartment.
Temperature of the heating vapor. . .	111.5° C.	97° C.	80° C.
Absolute corresponding pressure.	1.46 kilos	0.930 kilos	0.482 kilos
Average boiling temperature.	99.5° C.	85° C.	68° C.
Fall of temperature.	12° C.	12° C.	13° C.
Temperature of the resulting vapor. . .	97.5° C.	80.5° C.	58° C.
Absolute corresponding pressure.	0.943 kilos	0.491 kilos	0.184 kilos
Vacuum (cm.).	6.4	37.3	58.5

The boiling temperatures given above are not those of the total mass of juice contained in each compartment. They are in reality only one or two degrees higher than those of the escaping vapors.

Dessin's determination of the efficiency of a triple effect with compartment of same size.[1]—The evaporating efficiency of a triple effect with compartment of same size depends upon three factors: (1) Total heating surface; (2) fall of temperature between either sides of this heating surface; and (3) the coefficient of evaporation per hour per square meter and per degree of fall of temperature.

Supposed that the heating surface is 300 sq. m. distributed equally between the compartments. The fall of temperature which has already been determined is 12° C., and the coefficient of evaporation is supposed to be 2.5 kilos, that is to say, one square meter of

[1] This entire argument, depending upon compartments of same size, is very misleading, and should not be followed. The calculations are given with no other view than that of showing how the calculations may be made without the use of higher mathematics.—L. S. W.

heating surface will evaporate 2.5 kilos of water per hour and per degree of fall of temperature.

The total quantity of water evaporated per hour under these conditions will be $3\times100\times12\times2.5=9{,}000$ kilos, or, for 24 hours, $9{,}000\times24=216{,}000$ kilos or liters.

But the quantity of water to be evaporated in order to concentrate 100 kilos of juice from 9° to 45.83° Brix., or 5° to 25° Bé., is

$$100\left(1-\frac{9}{45.83}\right)=81.4 \text{ kilos}.$$

Consequently the quantity of juice concentrated per 24 hours, in an apparatus with 300 sq. m. heating surface, is

$$\frac{216{,}000\times100}{81.4}=265{,}356 \text{ kilos};$$

in which the density is 1.036, and which gives

$$\frac{265{,}356}{100\times1.036}=2{,}560 \text{ hl.}$$

This supposes that the evaporation efficiency per 24 hours is 8.53 hl. per square meter of heating surface, which is about what is actually obtained in the average triple-effect evaporator.

Dessin's determination of the efficiency of a triple effect with compartments of different sizes.—Before drawing any conclusion from what has been said in the foregoing, it is interesting to determine the efficiency of a triple effect with compartments of different sizes. Suppose that the heating surfaces are 78, 100, and 122 square meters, giving the same total as in the previous case. The evaporation being always the same in each compartment, and the coefficient of condensation a constant number, it necessarily follows that, if one of the other two factors varies, the third should vary inversely. In other words, if the heating surface progresses from compartment to compartment, it is necessary that the fall of temperature decrease in the same proportions; that is to say, in this special case the fall of temperature should be proportionate to 1:78, 1:100, and 1:122. The difference between the boiling temperature and that of the vapor obtained remains very slight, and will be about the same as that given for a triple effect with equal compartments. The total fall of temperature will conse-

quently be equal to about 36° C., and the actual fall of temperature in each compartment will be as follows:

$$\text{First compartment, } \frac{36\times\frac{1}{78}}{\frac{1}{78}+\frac{1}{100}+\frac{1}{122}}=14.88^\circ \text{ C.};$$

$$\text{Second compartment, } \frac{36\times\frac{1}{100}}{\frac{1}{78}+\frac{1}{100}+\frac{1}{122}}=11.60^\circ;$$

$$\text{Third compartment, } \frac{36\times\frac{1}{122}}{\frac{1}{78}+\frac{1}{100}+\frac{1}{122}}=9.51^\circ.$$

Under these conditions the amount of water evaporated per hour will be, in the

First compartment,	$78\times2.5\times14.88$	$=2,901$ kilos
Second compartment,	$100\times2.5\times11.60$	$=2,900$ "
Third compartment,	$122\times2.5\times9.51$	$=2,900$ "
	Total,	8,701 "

or, for 24 hours, $8,701\times24=208,824$ kilos.

This corresponds to the evaporation of

$$\frac{208,824}{81.4\times1.036}=2,476 \text{ hl.}$$

in 24 hours, and represents an evaporating efficiency of 8.25 hl. per square meter and per diem; that is to say, the efficiency is less than when the compartments are all of the same size.

This reduction in the efficiency of the effect will be more and more evident as the difference between the size of the compartments increases. Furthermore, if the difference is excessive, the average fall of temperature in the third compartment becomes so small that its lower portion is not utilized for the evaporation, and its rôle becomes simply that of a juice-reheater. This would reduce very considerably the efficiency of the apparatus, and consequently the maximum efficiency of a triple or multiple effect

in general can be attained only when all the compartments are of the same size.

It is frequently pointed out that these differences in size are the outcome of an effort to compensate for the deposits on the tubes by which the evaporating surface is diminished. According to DESSIN, these deposits are proportionate to the fall of temperature, and it would then be necessary that the proportion between the heating surfaces of these compartments be equal to them in each case, in order that the influence of the deposits might be felt equally in each section. The advantage still remains with the multiple effects of compartments of the same size, as the work accomplished is actually greater.

Horsin-Déon's method.—In what follows it is supposed that the compartments of the effect are all the same size. Horsin-Deon, like the authority mentioned in the foregoing, admitted the importance of that arrangement, providing that there was no outside heating to be accomplished. The apparatus to be considered meets the demands of a factory slicing 300 tons of beets per diem; it is claimed that there are extracted 4000 hl. of juice.

The 4000 hl. of juice from the diffusion battery are to be reduced to 800 hl. of syrup, and consequently 3200 hl. of water must be evaporated. It is supposed that the steam used for heating is at 112° C.; that, upon reaching the condenser, it is at 60° C.; and that the density of the juice upon entering the multiple effect is 1041, or 10° Brix. If we consider the fall of temperature, the boiling points of liquids, and also the average density of the juices in the three compartments, their corresponding specific heat, and the pressure-gauge indication of the apparatus, the following table is obtained:

Number of compartment.	Gauge in cm. pressure of mercury.	π Steam pressure in kilos per sq. centimeter.	p Water evaporated per hl.	D Average density.	C Sp. heat.	θ Temperature of the liquids.	T Temperature of the steam, deg. C.	V Sp. volume of the steam (volume of 1 kilo of steam) liters.
3	−61	.20	25.9	1.233	.60	63	60	7900
2	−30	.62	26.8	1.090	.90	87	86.5	2680
1	+3.5	1.08	27.8	1.054	.95	101.5	101.25	1630
Exhaust steam collector	+38	1.55	—	—	—	—	112	1200

If it is admitted that the juice is at a temperature of 80° C. upon its entrance into the three compartments, commencing with the third, the values of $t=87$, 101.5, and 80. With the data, and by a long argument and intricate calculation, the following formula is reached [1]:

$$S=\frac{p[A+(B-C)\Theta]\left[T-\dfrac{t+\Theta}{2}\right]}{(T-\Theta)\left[\dfrac{K}{V}\sqrt{2g(\pi-\pi')}\left(T-\dfrac{t+\Theta}{2}\right)[A+(B-1)T]-0.266(\Theta-t)D.C.\right]}$$

Substitute for the letters their corresponding values taken from the preceding table, and for the evaporation of one hectoliter per hour. The first compartment should have a heating surface, S, expressed by the following formula:

$$S=\frac{27.8}{112-101.5}\times\frac{[606.5+(0.305-0.95)101.5]\left[112-\dfrac{80+101.5}{2}\right]}{\left\{\dfrac{158.5}{1200}4.43\sqrt{155-108.1}\left(112-\dfrac{80+101.5}{2}\right)[606.5+(0.305-1)112]-0.266(101.5-80)1.054\times0.95\right\}}$$

This expression gives, for the first compartment, 0.670; for the second, the formula gives 0.716; and for the third, 0.708, or an average of about 0.700. It is concluded that the area needed for the evaporation in view is 400 sq. m.

Claassen's Method.—For the calculation of the heating surface of a multiple effect, Claassen argues in the following manner:

The coefficient of heat transmission means the quantity of heat transmitted per square meter in one minute for 1° C. fall of temperature. The coefficients of heat transmission have been determined by Jelinek.[2] They are, in the triple effect,—

for the 1st compartment, 37 calories per minute, per 1° C. and 1 sq. m.
for the 2d compartment, 25 do.
for the 3d compartment, 14 do.

and in the quadruple effect,—

for the 1st compartment, 28 calories per minute, per 1° C. and 1 sq. m.
for the 2d compartment, 26 do.
for the 3d compartment, 20 do.
for the 4th compartment, 5 to 6 do.

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[1] In this formula K is a factor determined by practical experiments, and is derived from the transmission coefficient. The liberated heat through the condensation of steam is expressed by the Régnault formula,

$$[A+[B-C]\Theta].$$

[2] Claassen, Zuckerfab. 315, 1901.

The total requisite heating surface is determined by dividing the total heat to be transmitted per minute, for each of the compartments considered separately, by the product of the fall of temperature and the coefficient of heat transmission. The fall of temperature in the reheaters is the difference between the temperature of the vapor or steam used for heating and the average temperature of the juice as it enters and leaves the apparatus; in the evaporating and graining appliance, it is the difference between the temperature of the vapor used for heating and that of the boiling juice.

This mode is very simple, but cannot be accepted as being mathematically exact. However, from a practical point of view it offers many advantages over all other modes, and, when discussing the PAULY-GREINER method of evaporation combined with reheating, further details will be given.

Increase in the efficiency of a multiple effect may be realized by increasing the fall of temperature and evaporating in thin layers, it being supposed that the total heating surface remains constant. DESSIN says that the first solution that presents itself in the fall-of-temperature problem is to force the pressure by the addition of live steam, and to increase the vacuo in the third compartment of the apparatus. But the increased pressure does not bring about the desired results, as there follows an increased counter-pressure upon the pistons of the steam engines. The vacuum in the third compartment may be increased a few inches by a change in the working of the condenser, but it is better to regulate the vacuum by the size of the air pump. Such modifications always involve a considerable alteration in the general plans of the factory, and it is better to adhere to the data already admitted. DESSIN showed that the theoretical fall of temperature in the compartments was 18° C., but practically only 12° C. in tubes 1.5 m. long and with regular working of the multiple effect. This difference is due to the height of the liquid to be raised by the escaping vapor, and is proportional to this height.

In the foregoing the differences between the boiling temperatures and that of the vapors obtained in each compartment were determined and found to be 2°, 4.5°, and 10° C. respectively. It may consequently be concluded that the height of the liquid in each case and the length of the tubes are of greater importance in the third compartment than in the first. Therefore, under ordinary conditions of working, when the maximum work is to be obtained from a given heating surface, it is necessary—

(1) To limit the length of the pipes of the apparatus, especially in the last compartment.

(2) To work the apparatus with the least possible juice circulating upon the tubular plates.

The reduction in the length of the pipes would cause the apparatus to increase in cost per unit of heating surface, and the transformation of existing types of apparatus along these lines would be impossible. On the other hand, a decrease in the height of the juice only above the tubular plates would not perceptibly increase the efficiency, for the reason that, in cases where the juice would be on the same level as the tubular disks, the total height of the juice would be reduced only from 1.68 m. to 1.50 m.

It was also proposed to reduce the boiling liquid to a very thin layer upon the heating surface by ruissellement, by means of which it becomes possible to do away entirely with the column of liquid, necessarily increasihg the fall of temperature. Owing to the constant renewing of the liquid, there would follow an increase in the coefficient of evaporation. Generally speaking, the amount of heat transmitted through the surface depends mainly upon the capacity of the liquid to absorb this heat through a natural or artificial circulation. Practically, it may be said that the heat furnished by the vapor to the surface is unlimited, provided, however, that the water of condensation upon the surface be removed as it is produced.

Some years since, the experiments of VIEDMANN and FRANZ demonstrated that the conductibility of brass was 116; that is to say, that the quantity of heat that could be transmitted per hour and per square meter of surface, with a thickness of one meter of brass and one degree difference in temperature, is 116 calories. This supposes a conductibility of

$$\left(\frac{116+1}{0.002}\right)=58{,}000 \text{ calories}$$

for a surface of one square meter, 2 mm. thickness and 1° C. fall of temperature.

If we suppose that, in the second compartment of a triple effect, one kilo of water demands for its evaporation

$$606.5+0.305\times 80.5-97=534 \text{ calories,}$$

it may be concluded that the coefficient of evaporation may reach

$$\frac{58,000}{534}=108.7 \text{ kilos},$$

provided the liquor could absorb all the heat transmitted by the surface. In previous calculations 2.5 kilos have been used as the coefficient. It is, therefore, the facility of absorption, and not the heating surface, that limits the amount of heat passing through, as long as the surface remains free of all deposits. Under all circumstances, the deposits in the interior of tubes reduce very considerably the transmissibility of the surface. The deposits, which in reality form a second surface made up of non-conducting substances, have a conductibility represented by 1.2 at a maximum; that is to say, about one one-hundredth that of brass. As these deposits influence the efficiency of the multiple effect, a preliminary treatment and filtration of the juices are desirable.

Numerous authorities could be cited showing that the transmission increases with the velocity; for example, with steam circulating through a copper pipe 10 mm. in diameter, 0.314 meters in length, and 1 mm. in thickness, the coefficient of transmission to water is only 1,400 at 0.10 velocity, and becomes 3,800 at 1.10 meters. In the appliances in actual existence, the vapor formed in the hottest part tends to give to the juice an upward circulation, which in certain cases causes a boiling above the tubular plate. The juice falling upon this disk tends to descend, and finally reaches the coolest portion of the tubular cluster. Such being the case, the evaporation is excessive in one portion of the compartment of a triple effect, and very slight or almost nothing in another. Consequently it is agreed that the average coefficient of evaporation seldom exceeds 2.5 kilos, as explained in the foregoing. This refers to a type of an average triple effect. The coefficient may reach 3 to 3.5 kilos for appliances working 10 to 12 hl. of juice per square meter and per diem, which is not uncommon, but demands special methods of working, low-level evaporation being among the conditions necessary to this result.

Determination of the evaporation efficiency under low level.—It is necessary in this connection to recall some of the previous calculations. The evaporating efficiency per hour, with compartments of the same size and 300 sq. m. heating surface, was expressed by the formula

$$3\times100\times12\times2.5=9,000 \text{ kilos},$$

in which 3×100 represents the total heating surface, 12 the fall of temperature, and 2.5 the coefficient of evaporation. If to this apparatus the two-thirds full principle is applied, the fall of temperature will reach 15° C., and the coefficient of evaporation will become 3. The quantity of water evaporated per hour will then be

$$3 \times 100 \times 15 \times 3 = 13{,}500,$$

which means an increase of 50 per cent. in efficiency over previous methods. Working with only one-third of the tubes covered means a fall of temperature of 17° C., and a coefficient of evaporation of 3.36. The apparatus will evaporate per hour under these conditions

$$3 \times 100 \times 17 \times 3.36 = 17{,}100 \text{ kilos.}$$

The efficiency will be thus increased by 90 per cent. This figure at first seems an exaggeration, but practical experience demonstrates that it is realizable.

Calculation relating to ruissellement.—DESSIN says that it is interesting to calculate, under these conditions, the thickness of the layer of liquid that would undergo the ruissellement with the best possible results. If the apparatus in question has a capacity of 15 hl. of juice per square meter and per diem (that is to say, an efficiency about double that of an average triple effect), the so-called circulating pump a capacity double that of the juice to be concentrated, and the tubes of the apparatus have a 50 mm. exterior and a 46 mm. interior diameter, and are 1.5 meters in length, there would be a heating surface of

$$0.503 \times .14 \times 15.00 = 23.5 \text{ sq. decimeters for each tube.}$$

In 24 hours there are concentrated by each tube

$$\frac{23.5 + 1500}{100} = 352.5 \text{ liters,}$$

or, per second,

$$\frac{352.5}{2 \times 604 \times 60} = 0.00487 \text{ liters.}$$

As the renewing of the juice represents two and a half times this volume, it necessarily follows that there will circulate in the first compartment, per tube and per second,

$$[2.5 + 1] \times 0.00487 = 0.017 = Q.$$

If the admitted hydrostatic charge is about 3 cm. upon the distributing opening, the theoretical velocity of the juice per second, upon passing out of the orifices, may be expressed by the formula

$$\sqrt{2gH},$$

in which $g=9.81$ and $H=0.03$ meters, to which it is necessary to add a coefficient in order to obtain the ruissellement velocity. Although this coefficient varies with each type of apparatus, it averages about 0.40. The velocity of the juice undergoing the ruissellement would be, under these conditions,

$$V=0.40\sqrt{2\times9.81\times0.03}=0.307 \text{ meters.}$$

Practical experiments and observations show that the acceleration due to gravity during ruissellement need not be taken into account. The velocity, 0.307, may be considered constant along the entire length of the tube. If E is the thickness of the ruisselling layer, and L the interior circumference of the tube, the development of the moistened surface, we have, for the output for each element, $Q=E\times L\times V$, from which deduct $E=\frac{Q}{LV}$.

Substituting for the letters their equivalents, which are $Q=0.017$, $L=0.46\times3.14=1.445$ $V=3.07$, we obtain

$$E=\frac{0.017}{1.445\times3.07}=0.0038 \text{ decimeter,}$$

or about 0.4 of a millimeter. The thickness of the layer of liquid during the ruissellement under these circumstances is hardly one third of a millimeter. It is to be noted that these calculations refer only to the first compartment, and that the volume of juice to be run through the last compartment becomes smaller; yet the circulating pumps remain of the same size, under which circumstances the thickness of the layer during ruissellement would be less.

At this phase of the juice's handling, steam economy plays a very important rôle; in fact, no issue in the whole problem of sugar-extraction is of greater importance than that of knowing how to save coal. It is interesting to examine the question from a practical standpoint. In what follows, the steam-consumption in a typical triple effect is considered.

Dessin's determination of the quantity of steam necessary in a triple effect.—It is interesting to determine what quantity of exhaust steam from the various engines of the factory would be necessary to produce the evaporation. With this idea in view it will be necessary to determine the quantity of heat carried away with the vapors, syrups, and condensed water taken from the apparatus, and from this to subtract the heat stored up in the juice upon entering the multiple effect. This difference is the heat furnished by the vapor during heating, and thus the weight of the latter may be determined.

It may be supposed that the condensed water taken from the tubular cluster is at the temperature of the steam or vapor from which it was obtained, an essential condition in order to reach the maximum fall of temperature. From the third compartment towards the condenser there escapes a weight of vapor at 58° C., which is one-third of the total evaporated, and carries with it

$$\frac{216,000}{3}(606.5+0.305\times 58)=44,942,400 \text{ calories.}$$

The syrup taken from the third compartment is at a temperature of about 60° C. Its weight is $265,356-216,000=49,356$ kilos, and it will carry out $49,356\times 60=2,961,360$ calories.

The water of condensation removed from the third tubular drum will be at 80° C.; its weight will be one-third of the total water evaporated, and it will remove

$$\frac{216,000}{3}\times 80=5,760,000 \text{ calories.}$$

The water of condensation from the second tubular drum at 97° C. will carry with it

$$\frac{216,000}{3}\times 97=6,984,000 \text{ calories.}$$

The total calories removed during evaporation consequently amount to 60,647,760, from which must be deducted the heat furnished by 265,356 kilos of juice, entering the first compartment at a temperature of 75° C., that is, $265,356\times 75=19,901,700$ calories, which leaves 40,746,060 calories. This difference should be supplied in the first tubular drum by the vapor produced at 111.5° C., which, after having been condensed and removed, will abandon

$606.5+0.305\times111.5-111.5=529$ calories. The apparatus would consequently need an amount of steam expressed by

$$\frac{40,746,060}{529.5}=76,950 \text{ kilos.}$$

As the apparatus evaporates 216,000 kilos of water, it may be concluded that 1 kilo of vapor will evaporate

$$\frac{216,000}{76,950}=2.80 \text{ kilos water.}$$

Principles of economy.—The principle of steam and consequently fuel economy is an issue that must be examined in some detail. It is interesting to ascertain what becomes of the total heat furnished by the steam generated in the boilers. In virtue of the principle of conservation of energy, the losses necessitated by the utilization of a portion of this heat for various stages of sugar extraction, added to the transformation of the other portion into mechanical work, should be equal to the total heat furnished to the steam by the coal burned under the boilers

In the foregoing calculations it was shown that the concentration of 2560 hl. of juice demands 76,950 kilos of exhaust steam, and that from the third compartment toward the condenser there escapes 72,000 kilos of steam, containing 44,492,400 calories. If we admit for an instant that the quantity of juice entering the triple effect be 16 hl. per 1000 kilos of beets that run through the slicer, it becomes evident that the 2560 hl. of juice come from 160,000 kilos of beets. If it is also admitted that the fuel consumption is 135 kilos per 1000 kilos of beets, and that this coal produces on an average 9.5 kilos of vapor, the total steam consumption will be

$$\frac{160,000}{1000}\times135\times9.5=205,200.$$

If we suppose that this vapor is at a pressure of 6 kilos at the boiler, and that, when used, it is under an average of only 5.5 kilos pressure, the corresponding temperature is about 154° C., and the amount of heat contained per kilo is $606.5+0.305\times154=653.5$ calories. As the water fed to the boiler is at the temperature of 75° C., the actual amount of heat furnished by the coal for one kilo of steam utilized in the factory is $653.5-75=578.5$ calories. The total heat furnished by the fuel necessary for the working of

160,000 kilos of beets, corresponding to 2560 hl. of juice entering the apparatus in twenty-four hours, and also the vapor needed in the other operations of the plant, contain $205,200 \times 578.5 = 118,708,200$ calories.

It has already been shown that 44,942,400 calories escape from the third compartment; that is to say, about 35 to 40 per cent. of the total heat furnished to the steam by the coal. It will presently be shown that, after the triple effect, it is during the graining in pan of first sugars that the greatest amount of caloric is absorbed, and that the heat taken up in the condensers represents more than one half of the calories furnished by the coal. For the other parts of the factory a certain amount of live steam, or steam at a lower pressure, is needed to furnish the requisite heat, and this amount cannot be reduced, owing to the special work to be done.

The quantity of heat transformed into motive power by the machines is comparatively small. The motors given forward to the evaporation an amount of heat almost equal to the total heat furnished. For example, the steam enters the cylinders of the engines at a pressure of 5.5 kilos, and contains per kilo a total heat of $606.5 + 0.305 \times 154 = 653.5$ calories. The steam enters the exhaust-steam collector at 112° C., when it still contains per kilo $606.5 + 0.305 \times 112 = 640.5$ calories, without making allowances for losses due to radiation. This expenditure of steam will be still reduced in a sugar factory with a well-combined evaporating plant.

It is during evaporation and graining that special effort should be made to economize fuel. The first idea that suggests itself is the reutilization of the vapors from the last compartment of multiple effects and the vacuum pan, but owing to their low density it is most difficult to handle them. A kilo of this vapor at 0.23 kilos absolute pressure, that is to say, 58° C., occupies a volume about equal to seven and a half cubic meters. In order to utilize the vapor it would become necessary to resort to compression, which would demand appliances of considerable size and would be in reality of very little practical value. There remains nothing but to reduce as much as possible the heat lost through the waters of condensation. To reduce the quantity of vapor escaping from the vacuum pan, there is only one method, which is to feed the pan with thick syrup, and with that idea in view it is necessary to increase the evaporating power of the multiple effect and to continue concentration until the desired limit is attained.

The reduction of the volume of vapor that is lost from the

triple effect may be accomplished in several ways. For example, take from the first compartment a certain amount of vapor for heating purposes, or begin the concentration of the juice before it enters the triple effect. These operations necessarily result in the reduction of the amount of work to be accomplished in the triple effect, and, furthermore, they reduce the total calories lost during the period of condensation. It is interesting now to study the question of multiple effect with four, five, and six compartments. It is self-evident that the amount of vapor escaping from the last compartment of a multiple effect is inversely proportional to the number of effects for a given concentration. The total fall of temperature for the apparatus must be considered as a whole, and the evaporating efficiency per square meter necessarily decreases with the number of compartments in the multiple effect. But as the cost of an evaporating plant increases with the area of its heating surface, there is an important advantage in having the evaporation as large as possible per unit of surface. In order to determine the extreme desirable limit for the number of compartments of a multiple effect a study must be made of the conditions for working more than three compartments.

It is necessary in this connection to recapitulate certain figures already given. A triple effect with 300 square meters heating surface working under ordinary conditions, that is to say, with tubular plates covered with 200 mm. of beet juice, will evaporate 9000 kilos of water per hour. This means an evaporating efficiency of 8.53 hl. of juice per square meter and per twenty-four hours. In the appliances under consideration one kilo of vapor will evaporate 2.8 kilos of water, and the same apparatus with ruissellement appliances is said to evaporate 15,200 kilos of water per hour. This supposes a work of 14.40 hl. per square meter and per diem.

Upon general principles it may be admitted that the greatest economy in a multiple effect is only realizable when the system is composed of the maximum number of compartments. The limit not to be exceeded is a subject to be discussed under another heading.

The Dessin mode of calculation of the economy of steam resulting from evaporation of thin layers is as follows: In the foregoing very little has been said respecting steam consumption, or the results expected from the introduction of the ruissellement methods. May an economy of steam and consequently of coal be effected through the use of ruissellement? The amount of

heat given up by one kilogram of vapor introduced into the first compartment of the apparatus and transformed into condensed water is a constant quantity at constant temperatures. This quantity of heat may be measured in calories, and is expressed by the REGNAULT formula

$$606.5+0.305\times T-T',$$

which has already been used in previous calculations, T representing the temperature of the steam at the time it is introduced into the drum and T' the temperature of the condensed water when leaving the drum. This formula is entirely independent of the evaporating efficiency, and is the same for all evaporating appliances, whatever be their mode of working. The increase in the amount of heat contained in one kilo of vapor at a constant temperature, without the assistance of any agent which draws its energy from a source of heat, would be a derogation of the universal principle which serves as a basis for physical science and which may be expressed as follows:

The total energy of a substance or a combination of substances is a quantity that cannot increase or decrease through the mutual action of these substances, notwithstanding the fact that it may be changed into any one of the forms that the energy may assume. These are heat, light, mechanical work, sound, electricity, chemical affinity, etc.

On the other hand, the vaporization of one kilogram of water demands an amount of heat which may be expressed by the same formula as before, in which T is the temperature of the vapor formed and T' that of water before boiling. This formula is independent of the evaporating apparatus. One may thus readily conclude that the quantity of water evaporated in multiple effect, consisting of a given number of sections, remains always the same, whatever may be the type of the apparatus. That is to say, considering evaporation only, there is no economy in transforming a triple effect into a ruissellement apparatus, for the reason that in the one case, as in the other, the amount of water evaporated per kilo of steam will be 2.8 kilos in a triple effect. However, in many cases the triple effect does not allow syrups to be obtained at the desired concentration, and then the vacuum pan must complete the work. In this apparatus one kilogram of vapor will hardly evaporate one kilo of water, and this method of working is certainly not economical. When the required concentration is not attained

with a given plant the ruissellement can be resorted to, but sugar factories with triple effects, giving syrups of the desired density, have no need for ruissellement appliances, as the simple application of ruissellement to existing triple effects will not result in any economy of fuel.

Evaporation in quadruple effects.—It is interesting to consider a quadruple effect with the same area of evaporating surface as the triple effect previously discussed.[1] This is divided into four compartments, each of which will have an area of $\frac{300}{4}=75$ sq. m. The conditions of working may be determined in the same manner as in the case of a triple effect and are given in the following table.

CONDITIONS OF WORKING IN A QUADRUPLE EFFECT.

Items.	First compartment.	Second compartment.	Third compartment.	Fourth compartment.
Temp. of vapor for heating (deg. C.)	111.5	98	84.5	71
Corresponding pressure (kilos)	1.460	0.975	0.578	0.331
Average boiling temperature (deg. C.)	98.5	85	71.5	58
Fall of temperature (deg. C.)	13	13	13	13
Temperature of the vapor produced (deg. C.)	98.5	85	71.5	58
Corresponding pressure (kilos)	0.980	0.590	0.337	0.184

This apparatus will evaporate per hour $4\times 75\times 13\times 2.9=11,310$ kilos, or 2712 hl. in twenty-four hours. The corresponding volume of juice is about 3220 hl. This shows an efficiency of concentration of 10.73 hl. per square mile of heating surface and per diem.

The consumption of vapor of this quadruple effect may be determined as follows:

There escapes, from the fourth compartment towards the condenser, vapor at 58° C., representing one-fourth of the total evaporation; in this way there is carried off $\frac{271,200}{4}(606.5+0.305\times 58)=$ 42,320,000 calories.

The weight of syrup removed from the fourth compartment at 58° C. is $(322,000\times 1.036)-271,200=60,800$ kilos. It carries with it $60,800\times 58=3,526,400$ calories. The water of condensation removed from the drum of the fourth compartment at 71° C. con-

[1] Here, again, the arguments and conclusions are not reliable and would be misleading.

tains $\frac{271,200}{4}\times 71=4,813,800$ calories. The water of condensation removed from the drum of the third compartment, at 84.5° C., contains $\frac{271,200}{4}\times 84.5=5,729,100$ calories. And the water of condensation removed from the second compartment, at 98° C., contains $\frac{271,200}{4}\times 98=6,644,400$ calories. Total calories removed during evaporation, 63,033,700 calories, from which there must be deducted the heat furnished by 3220 hl. of juice entering at 75° C. in the first compartment, or $(322,000\times 1.036)75=24,900,000$; difference, 38,133,700 calories.

As one kilo of condensed vapor in the first compartment abandons 529.5 calories, the total vapor consumption will be

$$\frac{38,133,700}{529.5}=72,018 \text{ kilos.}$$

The apparatus having evaporated a total of 2712 hl. of water, we may conclude that, in a quadruple effect, one kilo of vapor will evaporate

$$\frac{271,209}{72,018}=3.76 \text{ kilos of water.}$$

In the question of quintuple effect, we again suppose that the total evaporating surface is 300 square meters, divided into the five compartments, or 60 square meters for each. The conditions under which an appliance of this kind works are as follows:

CONDITIONS UNDER WHICH A QUINTUPLE EFFECT WORKS.

Items.	Compartments.				
	First.	Second.	Third.	Fourth.	Fifth.
Temperature of vapor for heating (deg. C.)	111.5	100.7	89.9	79.1	68.3
Corresponding pressure (kilos)	1.46	1.066	0.715	0.463	0.294
Av. boiling temperature (deg. C.)	101.2	90.4	79.6	68.8	58
Fall of temperature (deg. C.)	10.3	10.3	10.3	10.3	10.3
Corresponding absolute pressure (kilos)	1.078	0.73	0.475	0.300	0.184

This apparatus may evaporate per hour $5\times 60\times 10.3\times 2.9=8,960$ liters, or 2150 hl. in twenty-four hours. This corresponds to the

working of about 2550 hl., and supposes an efficiency of concentration of 8.5 hl. per square meter and per diem. To determine the vapor consumption, the calculations adopted in the foregoing are repeated. The amounts of heat carried away during evaporation are respectively as follows:

Through the vapors leaving the fifth compartment towards the condenser, $\frac{215,000}{5}\times(606.5+0.305\times58)=26,840,000$ calories; by the syrup of this same compartment $(255,000\times1.036-215,000)$, $58=2,847,800$ calories. By the water of condensation removed from the drum of the fifth compartment, $\frac{215,000}{5}\times68.3=2,936,800$ calories. By the water of condensation extracted from the fourth drum, $\frac{215,000}{5}\times79.1=3,401,300$ calories. By the water of condensation extracted from the third drum, $\frac{215,000}{5}\times89.9=3,865,700$ calories. By the water of condensation extracted from the second drum, $\frac{215,000}{5}\times100.7=4,330,100$ calories. Total, 44,221,800 calories, from which must be deducted the heat furnished by the juice upon entering the apparatus $(255,000\times1.036)75=19,807,000$. The difference is $44,221,800-19,807,000=24,414,300$ calories. The total consumption of vapor is $\frac{24,414,300}{529.5}=46,108$ kilos. The apparatus having evaporated 2150 hl. of water, it follows that, by the use of a quintuple effect, one kilo of vapor may evaporate $\frac{215,000}{46,108}$ $=4.66$ kilos of water. By repeating the calculations for a multiple effect with six compartments, it is found that one kilo of vapor will evaporate 5.54 kilos of water.

Consequences of multiple-effect evaporation.—With the idea of facilitating a comparison between multiple effects and their workings, there are given in a tabulated form (page 203) the practical results obtained by M. Dessin, with a given weight of beets passing through the slicer.

An examination of this table shows, what has already been explained, that the efficiency of concentration per unit of surface decreases with the number of compartments. With a sextuple effect, this efficiency is only 7 hl. per square meter and per twenty-four hours, showing why that form of a multiple effect has never

been successfully used. Admitting that the fuel consumption is 135 kilos of coal per 1000 kilos of beets, for the working of the triple effect alone there will be needed $135 \times 0.375 = 50.62$ kilos of coal; consequently this fuel consumption will be lessened, when working by a triple effect, to $135 - (50.62 \times 0.25) = 122.35$ kilos. With a quadruple effect it will be $135 - (50.62 \times 0.40) = 114.75$ kilos, and, with a sextuple effect, $135 - (50.62 \times 0.49) = 110$ kilos, or a decrease of 9.5 per cent, 15 per cent, and 18 per cent respectively in the total fuel consumption of the factory.

Working 160,000 kilos of beets, corresponding to 2560 hl.—Juice concentrated from 5 to 25° Bé. in 24 hours.	Triple effect regular working.	Ruissellement.			
		Triple effect.	Quadruple effect.	Quintuple effect.	Sextuple effect.
Evaporating efficiency per sq. m. and diem	8.53 hl.	14.4	10.73	8.5	7
Total surface requisite for heating equally distributed between the compartments	300 m.	177 m.	238.5m.	301 m.	366 m.
Coefficient of condensation	2.5	2.9	2.9	2.9	2.9
Total fall of temp. (112 − 58 = 54)	54° C.	54° C.	54° C.	54° C.	54° C.
Actual fall of temperature in each compartment	12° C.	17.5° C.	13° C.	10.3° C.	8.5° C.
Weight of water evaporated by 1 kilo of steam	2.8 k.	2.8 k.	3.76 k.	4.66 k.	5.54 k.
Total weight of steam consumed by evaporation (kilos)	76,950	76,950	57,440	46,350	39,000
Determined quantity of steam consumed as compared with the total absorbed by the factory, which is 205,200 kilos	37.5%	37.5%	28%	22.5%	19%
Determined weight of steam consumed compared with that of triple effect	100%	100%	75%	60%	50%

These differences would have been still greater if, in the original plant with triple effect, some live steam had been used for the evaporation. The maximum economy can be realized only by the combination of this evaporation in multiple effect with various heating, by improvements in the steam engines, by the reduction of the losses of heat through radiation and other losses, and with a well-arranged series of boilers. If we suppose that the machinery alone furnishes the steam necessary for evaporation, it will be necessary to make special arrangements for the maintenance of their efficiency, with a decrease in their steam consumption. In the foregoing discussion it has been supposed that the concentra-

tion of the juice and of the syrup extracted has been the same in each case. If changes are made in a triple effect, formerly producing only moderately concentrated syrups, and through these changes thick syrups are obtained, it necessarily follows that fuel has been saved, and this economy should be added to that mentioned above. Each factory must be made the subject of a special study, so that the varying conditions may be considered.

CHAPTER XI.

CALCULATIONS RELATING TO MULTIPLE-EFFECT REHEATING.

UNDER another caption, the main issues of steam economy are discussed in a general way. The steam and vapor consumed at the several stations of the sugar factory are estimated, per hectoliter of diffusion juice, by HORSIN-DÉON,[1] as follows:

	Kilos.
Diffusion	4.4
First carbonatation	8.0
Second carbonatation	7.5
Reheating of juices before evaporation	3.5
Triple effect evaporation $\left[\frac{80}{3}\text{ kilos water evaporated}\right]$	26.7
Heating of syrups	1.0
Graining—First strike	8.0
Graining—Other strikes	1.7
In centrifugals and radiations	10.0
	70.8

On the other hand, DESSIN determines the steam consumption for a factory working with an ordinary triple effect, and in which all the heating is done either with live or exhaust steam. In what follows, no allowance is made for the specific heat, nor for the losses through radiation. The relations existing between the juice, syrup, etc., are taken only as a basis for comparison and are not standard, for they vary from one factory to another.

Heating with live steam. Calculations of the steam consumption of a factory using the regular appliances.—In the case examined, it is supposed that the plant slices 200 tons of beets per diem.

[1] HORSIN-DÉON, Traité, II, 2, 641, 1900.

Diffusion.—The quantity of juice drawn off is 120 per cent at 1.046 density and at a temperature of 28° C.

The temperature of the cossettes, and the water with which they are combined at the moment of drawing off, is at 22° C.

The temperature of the beets and of the water in the pressure tank is 25° C.

The total juice drawn off per diem is $120 \times 2000 = 240{,}000$ liters, or $240{,}000 \times 1.046 = 251{,}040$ kilos.

The total number of calories necessary in working the diffusion battery may be ascertained by considering the total number of calories contained in the various elements leaving the battery. The juice carries off

$$251{,}040 \times (28-15) = 3{,}263{,}520 \text{ calories;}$$

the cossettes carry off

$$1.05 \times 200{,}000 \times (22-15) = 1{,}470{,}000 \text{ calories}$$

(it being supposed that the weight of the cossettes is 105 per cent of the beets sliced); the water carries off

$$0.95 \times 200{,}000 \times (22-15) = 1{,}330{,}000 \text{ calories}$$

(this supposing the water used to have a weight corresponding to 95 per cent of the beets sliced). Consequently we have a total of 6,063,520 calories. To this may be added the heat absorbed by the metallic portions of the battery, which are successively heated and cooled, resulting in considerable losses through this extended surface of radiation. However, in these calculations no allowance is made for such losses.

To calculate the quantity of steam consumed, it may be supposed that the pressure in the boilers is 6 kilos, and that the pressure of steam at its entrance into the calorizators is only 5 kilos, or 158° C.; furthermore, the condensed water leaving this appliance is at 102° C. Under these conditions, one kilogram of condensed steam abandons

$$606.5 + 0.305 \times 158 - 102 = 552.7 \text{ calories.}$$

The total steam consumed by the battery is

$$\frac{6{,}063{,}520}{552.7} = 10{,}975 \text{ kilos, or}$$

$$\frac{10{,}975}{200} = 54.87 \text{ kilos per ton of beets sliced.}$$

First carbonatation.—The quantity of juice drawn off during diffusion is 251,040 kilos. Milk of lime, added in the proportion of 12 per cent, amounts to 30,200 kilos, giving 281,240 kilos for the total juice of first carbonatation. This is heated from 25° C. to 65° C. before saturation, absorbs 281,240 $(65-25)=11,249,600$, and the heating is then continued from 65° to 90° C., giving 281,240 $(90-65)=7,031,000$, or a total of 18,280,600 calories, and demanding $\frac{18,280,600}{552.7}=33,117$ kilos of steam; or $\frac{33,117}{200}=165.5$ kilos per ton of beets sliced.

Second carbonatation.—The quantity of juice from first carbonatation is 281,240 kilos. The sweet water from the filter presses represents 100 per cent of the filter press scums, the latter being estimated at 12 per cent of the total beets sliced, or 2400 kilos, to which must be added about 4 per cent of milk of lime, or 11,300 kilos.[1] The total, therefore, is 294,940 kilos for the total juice of second carbonatation.

Heating from 65° C. to 95° C. will absorb

$$294,940\times(95-65)=8,848,200 \text{ calories;}$$

raising it to boiling point, from 90° C. to 100° C., will further absorb

$$294,940(100-90)=2,949,400 \text{ calories,}$$

or a total of 11,797,600 calories, which will require

$\frac{11,797,600}{552}=21,373$ kilos of steam, or $\frac{21,373}{200}=106.9$ kilos per ton of beets sliced.

Reheating of the juice before filtration.—The quantity of juice from the second carbonatation is 294,940 kilos, and this must be heated from 70° to 100° C. before filtration,[2] demanding

$$294,940(100-70)=8,848,200 \text{ calories, or}$$

$\frac{8,848,200}{552}=16,030$ kilos of steam, meaning $\frac{16,030}{200}=80.10$ kilos per ton of beets worked.

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[1] This should not be allowed for, as the sweet waters are always returned in the milk of lime.

[2] It is not reasonable to suppose that these juices passing through the filter presses should be cooled from 100° to 70° C.

Evaporation in triple effect.—The quantity of juice from second carbonatation is 294,940 kilos, and from the washing filters, 1,500 kilos, or a total of 296,440 kilos of juice entering the multiple effect. To concentrate 296,440 kilos of juice from 5° to 25° Bé. necessitated the evaporation of

$$\frac{296,440 \times 81.4}{100} = 242,192 \text{ kilos of water,}$$

demanding a consumption of

$$\frac{242,192}{2.8} = 86,500 \text{ kilos of steam,}$$

and this would require an expenditure of

$$86,500 \times 529.5 = 45,801,700 \text{ calories,}$$

corresponding to

$$\frac{86,500}{200} = 432.5 \text{ kilos of steam per ton of beets sliced.}$$

Reheating of syrup.—The quantity of syrup drawn from the multiple effect is $296,440 - 242,192 = 54,248$ kilos. This must be heated from 60° to 100° before filtration and demands

$$54,248(100-60) = 2,169,920 \text{ calories, or}$$

$$\frac{2,169,920}{552} = 3913 \text{ kilos of steam, meaning}$$

$$\frac{3913}{200} = 19.56 \text{ kilos per ton of beets sliced.}$$

Graining first sugars.—If there are 10 liters of *massecuite* per 100 kilos of beets, the total weight would be

$$\frac{200,000 \times 15}{100} = 30,000 \text{ kilos.}$$

The quantity of syrup producing this massecuite is 54,248 kilos, and consequently the water to be evaporated is

$$54,248 - 30,000 = 24,248 \text{ kilos.}$$

Evaporated in vacuo these 24,248 kilos of vapor will have an average temperature of 70° C., and will carry off

$$24{,}248(606.5+0.305\times 70)=15{,}224{,}100 \text{ calories,}$$

to which must be added the heat carried off by the 30,000 kilos of massecuite leaving the pan at 80° C., or

$$30{,}000\times 80=2{,}400{,}000 \text{ calories,}$$

or a total of 17,624,000 calories, from which must be deducted the heat brought by the 54,248 kilos of syrup entering the pan at 75°,

$$54{,}248\times 75=4{,}068{,}600.$$

Consequently the total calories expended for graining fruit sugars is

$$17{,}624{,}000-4{,}068{,}600=13{,}555{,}400 \text{ calories,}$$

representing $\frac{13{,}555{,}400}{552}=24{,}557$ kilos of steam, or

$$\frac{24{,}557}{200}=122.80 \text{ kilos per ton of beets sliced.}$$

Graining after-products.—It is supposed that the after-product represents 4.5 liters per 100 kilos of beets sliced, or

$$4.5\times 2000=9000 \text{ liters.}$$

This, at 35° Bé. (65.2° Brix), is 11,800 kilos, from which must be evaporated $11{,}800\times 1-\left(\frac{65.2}{81.47}\right)=2376$ kilos of water. The weight of the massecuite would be

$$11{,}880-2376 \text{ kilos}=9504 \text{ kilos.}$$

The water evaporated in vacuo at an average temperature of 70° C. carries away with it

$$2376\times(605.5+0.305\times 70)=1{,}551{,}772 \text{ calories,}$$

to which must be added the heat carried off by the massecuite,

$$9504\times 80=760{,}320,$$

giving a total of 2,212,092 calories. The after-product at 30° C. entering the pan furnishes an amount of calories represented by

$11,880 \times 30 = 356,400$, which must be deducted, and there remains 1,855,692 calories. This requires

$$\frac{1,855,692}{552} = 3360 \text{ kilos of steam, or}$$

$$\frac{3360}{200} = 16.8 \text{ kilos per ton of beets sliced.}$$

Heating crystallizing tanks.—If the final after-product is left in tanks that are kept warm for a certain period, the total heating surface of the pipes is 40 square meters, and the condensation 2 kilos per hour and per square meter, the steam needed would be

$$40 \times 2 \times 24 = 1,920 \text{ kilos per diem, or}$$

$$\frac{1920}{200} = 9.6 \text{ kilos per ton of beets sliced.}$$

DESSIN, who is responsible for the foregoing calculations, gives a synopsis of them in the following table.

DESSIN'S TABLE.

Phase of manufacture.	Heat expended per diem, slicing 200 tons of beets.	Steam consumed per diem, 200 tons of beets sliced.	Steam consumed per 1000 kilos of beets.
	Calories.	Kilos.	Kilos.
Diffusion	6,063,520	10,975	54.87
First carbonatation	18,280,000	33,117	165.50
Second carbonatation	11,797,600	21,373	106.90
Reheating of juice	8,848,200	16,030	80.10
Evaporation	45,801,700	86,500	432.50
Reheating of syrup	2,169,920	3,913	19.56
Graining—First	13,555,400	24,557	122.80
Graining—Second	1,855,692	3,360	16.80
Heating after-products	1,059,840	1,920	9.60
Totals	109,431,872	201,745	1008.63

It is interesting to note what quantity of fuel would be necessary. If it is admitted that the boilers evaporate 8.75 kilos of water per kilo of coal, it may be concluded that the coal consumption in the factory under consideration is

$$\frac{1008.63}{8.75} = 115 \text{ kilos per ton of beets sliced.}$$

From the foregoing calculation certain conclusions may be drawn. In the table there may be noticed two ways of using steam.

1. Various kinds of heating prior to the extraction, evaporation, or filtration of juices, syrup, and after-products.

2. Evaporation and graining.

The third use of steam for obtaining the motive power is not given, for it has been supposed that there are no losses. During diffusion the caloric furnished by the steam is indispensable for the extraction of the juice. During carbonatation the heating prepares the juices for their chemical treatment, and they are prepared in the same way for filtering, etc. It may be said that generally the caloric is well utilized and very little economy is realizable in that direction. Attention should consequently be limited to improving the apparatus and diminishing the loss through radiation.

As was shown, the evaporation required 45,801,700 calories, and, if the previous calculations regarding triple effects be examined, it will be found that the amount of steam leaving the third compartment and passing into the condenser is

$$\frac{242,192}{3}=80,730 \text{ kilos.}$$

This carries off

$$606.5+0.305\times 58=624.2 \text{ calories per kilo, or}$$

$$80,730\times 624.2=50,400,000 \text{ calories.}$$

It is to be noted that the total heat escaping from the third compartment is greater than that which was utilized in the first compartment.

The graining of the first sugars needed 13,355,400 calories, to which must be added a portion of the heat furnished by the syrup, giving a total of 15,224,100 calories carried off into the condenser. The graining of the seconds demanded 1,855,692 calories and abandoned 1,171,172 calories to the injection water. The total heat taken up by the condensation is consequently

$$50,400,000+15,224,100+1,551,772=67,175,872 \text{ calories,}$$

amounting to more than half the entire heat used throughout the factory. This is an absolute loss, and if it were possible by some means to recover it, the resulting fuel economy would be not less than 50 per cent.

The first idea that naturally suggests itself is that some practical means be adopted for the reutilization of the steam leaving

the multiple effect and vacuum pan. When submitted to pressure, this steam would have such a tension and temperature as would enable it to render important service. It is pointed out that owing to the low density, the compressors would have to be of enormous size even for a small factory. One kilo of this vapor has a volume of 6 to 7 cu. m., which shows the practical impossibility of resorting to compression.

However, it is possible to use a portion of this steam by placing on its passage suitable tubular reheaters for cold juice or water, These vapors have a temperature varying from 58° to 60°, and frequently more. By the use of reheaters properly arranged and understood it is possible to heat juices on their way to the first carbonatation to 52° C., or in the same manner to heat water for the diffusion battery in separate appliances. If it is admitted that the water entering the battery is at 35° to 40° C. instead of 15° C., this would evidently cause an important fuel saving, and the caloric economy would be equivalent to the heat carried off by the residuary water and cossettes from the battery, or

$$1,470,000 + 1,330,000 = 2,800,000 \text{ calories,}$$

representing about

$$\frac{2,800,000}{552} = 5070 \text{ kilos of steam; or}$$

$$\frac{5070}{200} = 25.35 \text{ kilos per ton of beets sliced,}$$

or in other words $\frac{25.35}{8.75} = 2.9$ kilos of coal.

As hot water is used in the diffusion battery, the juices upon leaving the diffusors would be at a higher temperature than that supposed in the previous calculations, and if it passes through another reheater, receiving its heat from the waste steam, its temperature could be raised there to 52° C., and would be 50° C. when entering the carbonatation tanks. This would represent a heat economy of

$$281,240 \times (50 - 25) = 7,031,000 \text{ calories, or}$$

$\frac{7031,000}{552}=12,730$ kilos of steam, or $\frac{12,730}{200}=63.65$ kilos per 100 tons of beets worked. As this represents

$$\frac{63.65}{8.75}=7.27 \text{ kilos of coal,}$$

the consequent fuel economy would be $2.90+7.27=10.17$ kilos per ton of beets sliced per diem. If a factory of 500 tons is considered this represents 5000 kilos, or five tons, and for a 100-day campaign, 500 tons, or $2500, based upon European prices. This saving may be still greater when taking slicing stations into consideration, from which the central factories receive the juice at a temperature of from 5° to 8° C.

Steam consumption with Lexa-Rillieux's system.—No modern beet-sugar factory uses live steam for heating the juice at various stages through which it passes. It is interesting to study the fuel economy resulting from the use of the LEXA-RILLIEUX system and other similar methods. In the DESSIN calculation it is supposed that there is a quadruple effect in which the first compartment supplies all the vapor needed for heating at temperatures of from 90° to 100° C.; the second compartment all the vapor needed when the heating is to be done at 80° to 90° C., and it is under these circumstances that the juices are heated from 25° to 80° C. on their way to the first carbonatation tank. It is also supposed that under these conditions of working there is a fall of temperature of 18° C. between every compartment. No account is taken of the influence of the column of liquor nor of the losses of heat.

DATA USED IN THE DESSIN CALCULATION.

Conditions of operation.	First compartment.	Second compartment.	Third compartment.	Fourth compartment.
Temperature of heating vapor (deg. C.)	124	108	91	73
Approximate absolute pressure of the heating vapor (kilos)............	2.25	1.3	0.7	0.35
Temperature of the evolved vapor (deg. C.)......................	108	91	73	55
Approximate absolute pressure of the evaporated vapor (kilos)........	1.3	0.7	0.35	0.15

The vapor produced at 108° C. in the first compartment is utilized in reheaters to raise the temperature of the juice and syrup to nearly 100° C. The reheater for first carbonatation juice

will raise the temperature to 80° C. with the vapor from the second compartment, which is at 91° C.

The live-steam consumption at each stage of manufacture is then as follows:

First diffusion.—The direct steam consumption during the operation of diffusion will be the same as previously, or 10,975 kilos for a factory slicing 200 tons of beets per diem, representing 6,063,520 calories, or 54.87 kilos per ton of beets sliced.

Second carbonatation.—The consumption of live steam for first and second carbonatation need not be considered, because before it reaches these receptacles the juice is heated in the reheaters with the vapor from first compartment.

Third reheating of the juices and syrup.—Consumption of steam in this case is also zero, for the reason that the juices and syrups are heated with vapors from the multiple effect.

Fourth evaporation.—The calculation relating to the consumption of steam during evaporation is a little more complicated in the case under consideration than it was for a triple effect. It is proposed that the water evaporated in each of the third and fourth compartments shall be termed Z. Let Y be the quantity of vapor produced in the second compartment, and X the vapor liberated in the first. It is evident that the quantity Y of vapor produced by the second compartment is equal to Z produced in the third, increased by that condensed in the reheater for first carbonatation juice. In this reheater the temperature of the 281,240 kilos of juice passing through is raised from 25° to 80° C., which represents an amount of heat equal to

$$281{,}240 \times (80-25) = 15{,}468{,}200 \text{ calories.}$$

The vapor is sent to the reheater at 91° C. and the condensed water extracted at 73°, abandoning, per kilo,

$$606.5 + 0.305 \times 91 - 73 = 543.2 \text{ calories.}$$

The reheating of the first carbonatation juice demanded

$$\frac{15{,}468{,}200}{543.2} = 28{,}476 \text{ kilos of steam}$$

from the second compartment. The quantity of water evaporated will be $Y = Z + 28{,}476$. The total vapor produced in the first compartment will be equal to Y, increased by that consumed in the

other reheaters. The reheater in communication with the second carbonatation raised 294,940 kilos of juice from 60 to 100° C. This required

$$294{,}940 \times (100-60) = 11{,}797{,}600 \text{ calories.}$$

The reheating of 294,940 kilos of juice before filtration from 70° to 100° C. required

$$294{,}940(100-70) = 8{,}848{,}200 \text{ calories.}$$

Finally, the reheating of 54,248 kilos of syrups before the filtrat on from 60° to 100° C. takes

$$54{,}248(100-60) = 2{,}169{,}920 \text{ calories.}$$

Consequently, the total calories furnished by the first compartment to the various heating appliances are

$$11{,}797{,}600 + 8{,}848{,}200 + 2{,}169{,}920 = 22{,}815{,}720 \text{ calories.}$$

This vapor, which is introduced into the reheater at 108° C and leaves after being condensed at 91°, yields

$$606.5 + 0.305 \times 108 - 91 = 548.5 \text{ calories.}$$

The total steam from the first compartment consumed by the reheaters will consequently be

$$\frac{22{,}815{,}720}{548.5} = 41{,}596 \text{ kilos;}$$

and the total water evaporated in the first compartment will be

$$X = Y + 41{,}596 = Z + 28{,}476 + 41{,}596$$
$$X = Z + 70{,}072.$$

If the previous calculations be examined, it will be seen that the concentration of the juice demanded the total evaporation of 242,192 kilos of water, equal to the total water evaporated in each compartment, and consequently $X+Y+Z+Z=242{,}192$, and replacing the letters by their equivalents, $Z=35{,}911$ kilos. The evaporation in each of the compartments will be, respectively,

		Kilos.
First compartment	35,911 + 70,072 =	105,983
Second compartment	35,911 + 28,476 =	64,387
Third compartment		35,911
Fourth compartment		35,911
		242,192

If the total calories taken off and furnished for the evaporation is passed in review, as has already been done in a previous example for a triple effect, the following figures will be obtained:

Calories taken off by 35,911 kilos of vapor leaving the fourth compartment. . . . . 35,911 × (606.5 + 0.305 × 55)	= 22,379,735
Calories removed by the syrup leaving the multiple effect 54,248 × 58	= 3,144,784
Calories removed by the condensed water leaving the fourth compartment. . . . . 35,911 × 73	= 2,621,503
Calories removed by the condensed water in the third compartment. . . . . 35,911 × 91	= 3,267,901
Calories removed by the condensed water in the second compartment. . . . . 64,387 × 108	= 6,963,796
Calories removed by the condensed water in the reheater for first carbonatation juice. . . . . 28,476 × 73	= 2,078,748
Calories removed by the condensed water in the other reheaters 41,596 × 91	= 3.785,236
Calories removed by the juices passing through all the reheaters 15,468,200 + 22,815,720	= 38,283,920
Total heat removed through the evaporation and heating. . . .	= 82,515,623

From this total must be deducted the heat furnished by 296,440 kilos of juices entering the first compartment of the quadruple effect, or 21,333,000 calories, leaving a total heat expended of 61,182,623 calories.

One kilo of steam entering the first compartment at 124° C. and leaving at 108° will have abandoned

$$606.5 + 0.305 \times 124 - 108 = 536.3 \text{ calories.}$$

The quantity of steam necessary for the first compartment in a LEXA-RILLIEUX combination, such as explained just now, will consequently be

$$\frac{61,182,623}{536.3} = 114,083 \text{ kilos}$$

for a 200-ton plant, or 570.41 kilos per ton of beets sliced.

As it has been admitted that the exhaust from the engines of the factory is 86,500 kilos, the actual amount of live steam to be furnished to the first compartment will be 27,583 kilos.

Graining of first sugars.—The steam expenditure for the graining of first sugars wi'l be the same as it was in the previous case, 24,557 kilos, and will represent 13,555,400 calories, or 122.8 kilos per ton of beets sliced.

Graining of second sugars.—The expenditure for this graining will be 3360 kilos, equivalent to 1,855,692 calories, or 16.8 kilos of steam per ton of beets sliced.

Heating of the crystallizing tanks.—For this purpose it was supposed that there is needed 1920 kilos of steam, or 1,059,840 calories, equal to a consumption of 9.6 kilos per ton of beets sliced.

A general synopsis of what has been said is given in the following table:

STEAM CONSUMPTION.

Station of extraction.	Heat expended daily for working 200 tons of beets per diem.	Steam consumed for the working of 200 tons of beets per diem.	Steam consumed per ton of beets sliced.
	Calories.	Kilos.	Kilos.
Diffusion	6,063,520	10,975	54.87
First carbonatation			
Second carbonatation			
Reheating of juice			
Evaporation	61,182,623	114,083	570.41
Reheating of syrup			
Graining first sugars	13,555,400	24,557	122.80
Graining second sugars	1,855,392	3,360	16.80
Heating crystallizing tanks	1,059,840	1,920	9.60
Totals	83,717,075	154,895	774.48

Based on what has been previously said, these figures show a uel expenditure of

$$\frac{774.48}{8.75}=88.5 \text{ kilos per ton of beets sliced.}$$

This amount will probably be increased by 10 to 25 per cent in practice, the amount depending upon the arrangement of the local plant.

It should be pointed out that, as there is a very slight difference between the temperature of the juice entering the reheaters and the circulating vapor, it is most important to have the heating surfaces of the reheaters as large as possible; hence the advantage of having several, and of keeping them free from all deposits, so as to realize the greatest possible efficiency. Another issue of vital importance is the circulation, and the removal of the condensed water and all inert gases.

HORSIN-DÉON'S method of calculating the steam consumption for a factory working by the LEXA-RILLIEUX method is also of interest. Reference must be made to previous calculations by the

same expert, who gave the steam consumed per hectoliter of juice at different stages of beet-sugar manufacture. It is supposed that the apparatus consists of a triple effect, in which the first compartment has a heating surface double that of the second and third compartments. The surface of this first compartment has double the evaporating efficiency of the others. As the problem demands the evaporation of 80 kilos of water, the first compartment will evaporate 40, the second 20, and the third 20 kilos. The first compartment furnishing only 20 kilos to the second, there will remain 20 kilos for the heating. The steam and vapor consumption will be as follows:

	Kilos.
Diffusion	4.4
First compartment, triple effect	40.0
Graining, first	8.0
Graining, second and third	1.7
Centrifugal and losses	10.0
Total	64.1

instead of 70.8 kilos, as needed by previous calculations, or 9.5 per cent economy of steam. No allowance is made for the reheating, as it is accomplished with the vapors of the first compartment.

Dessin's calculation of the steam consumption in a factory working by the Pauly-Greiner method.—The heating surface of the fore-evaporator is calculated on the basis of a maximum fall of temperature that varies from 15° to 20° C. in order to prevent an excessive boiling and entraînement of the juice. Dessin supposes the following conditions:

Approximate effective pressure of the live steam used in the fore-evaporator (kilos)	2.50
Corresponding temperature (deg. C.)	138
Approximate effective pressure of the vapor evolved from the juice in the fore-evaporator (kilos)	1.25
Corresponding temperature (deg. C.)	123

It is supposed that a recuperator is used, that the recuperation is complete, and that the juice enters at 120° C. into the fore-evaporator, and at 78° C. into the first compartment of the multiple effect. At each station the heating from 90° to 100° is done with the vapors of the fore-evaporator. Diffusion in this case remains the same as in the previous example for Lexa-Rillieux heating.

First and second carbonatation live-steam consumption need not

be considered, for the fore-evaporator furnishes all the necessary caloric. Neither is any actual consumption of live steam necessary for heating the juices and syrup, and the same is true for the graining of first sugars and other products.

Fore-evaporator. — The heat consumption of this apparatus equals the amount of heat necessary to raise the juice to the boiling temperature, plus that carried off by the vapors of the juice for the various heatings. The quantity of juice entering the fore-evaporator is 296,440 kilos; its temperature is raised from 120° to 123° C., demanding

$$296,400 \times (123 - 120) = 889,320 \text{ calories.}$$

The reheating of 281,240 kilos of juice from 25° to 90° before first carbonatation requires

$$281,240 \times (90 - 25) = 18,280,600 \text{ calories.}$$

The reheating of 294,940 kilos of juice from 60° to 100° before second carbonatation consumed, as already explained, 11,797,600 calories; the heating of juice before filtration required 8,848,200 calories; the reheating of the syrup, 2,169,920 calories; graining first sugars in pan, 13,555,400 calories; graining the after-products, 1,855,962 calories; or a total for the fore-evaporator of 57,396,732 calories. One kilo of direct steam, introduced at 138° and leaving at 102°, will have abandoned

$$606.5 + 0.305 \times 138 - 102 = 546.5 \text{ calories.}$$

The direct consumption of steam in the fore-evaporator is

$$\frac{57,396,732}{546.5} = 105,026 \text{ kilos, or } 525.13 \text{ kilos}$$

per ton of beets sliced.

Evaporation.—As already explained, the quantity of heat absorbed by the heating effected by the vapor of the fore-evaporator is

$$57,396,732 - 889,320 = 56,507,412 \text{ calories.}$$

One kilo of juice vapor, produced at 123° and condensed to 100°, will give off

$$606.5 + 0.305 \times 123 - 100 = 543 \text{ calories.}$$

The quantity of water evaporated by the fore-evaporator, and distributed as vapor to various stations of the factory, is

$$\frac{56,507,412}{543} = 104,065 \text{ kilos.}$$

As the total water to be evaporated, as previously explained, is 242,192 kilos, the supplementary evaporation to be effected is

$$242,192 - 104,065 = 138,127 \text{ kilos.}$$

The juice enters the multiple effect at 78° C., instead of 75° C., as previously stated, and it follows that one kilo of exhausted steam may evaporate 2.8 kilos of water. It is concluded that the consumption of steam of the triple effect under consideration is

$$\frac{138,127}{2.8} = 49,960 \text{ [1] kilos, or}$$

$$49,960 \times 529.5 = 26,453,820 \text{ calories:}$$

$$\frac{49,960}{200} = 249.8 \text{ kilos of steam per ton of beets sliced.}$$

The foregoing calculation may be tabulated as follows:

CALCULATION OF HEAT AND STEAM CONSUMPTION IN A PAULY-GREINER PLANT WITH A TRIPLE EFFECT.

Stage of manufacture.	Heat consumed per diem for 200 tons of beets.	Steam consumed per diem for 200 tons of beets.	Steam consumed per ton of beets sliced.
	Calories.	Kilos.	Kilos.
Diffusion	6,063,520	10,975	54.87
First carbonatation			
Second carbonatation			
Reheating of juice			
Fore-evaporator	57,396,732	105,026	525.13
Evaporation	26,653,820	49,960	249.80
Reheating syrup			
Graining first sugar			
Graining second sugar			
Heating crystallizing tanks	1,059,840	1,920	9.60
Totals	90,973,912	167,881	839.40

If we suppose an evaporation of 8.75 per kilogram of coal in the boilers, we would have

$$\frac{839.40}{8.75} = 96.73 \text{ kilos per ton of beets sliced.}$$

In German factories a fore-evaporator is frequently combined with the quadruple effect, and the quantity of steam needed for the evaporation is then still further reduced.

[1] This should be 49.331, but has been allowed to stand as given, as the change would complicate the data that follow. Some other small errors have been allowed to remain for the same reason.

As shown in the foregoing calculation, the amount of water to be evaporated in the multiple effect is 138,127 kilos in the case of a 200-ton plant. If the apparatus is a quadruple effect, it could then evaporate 3.76 kilos of water per kilo of steam.

The steam consumption then is

$$\frac{138{,}127}{3.76}=36{,}735 \text{ kilos,}$$

meaning 36,735×529.5 calories = 19,450,482 calories; or

$$\frac{36{,}735}{200}=183.67 \text{ kilos per ton of beets sliced.}$$

The foregoing table then reads as follows:

CALCULATION OF HEAT AND STEAM CONSUMPTION IN A PAULY-GREINER PLANT WITH A QUADRUPLE EFFECT.

State of manufacture.	Heat consumed per diem for 200 tons of beets.	Steam consumed per diem for 200 tons of beets.	Steam consumed per ton of beets sliced.
	Calories.	Kilos.	Kilos.
Diffusion	6,063,520	10,975	54.87
First carbonatation			
Second carbonatation			
Reheating of the juice			
Fore-evaporator	57,396,732	105,026	525.13
Evaporation	19,450,482	36,735	183.67
Reheating syrups			
Graining first sugars			
Graining second sugars			
Heating crystallizing tanks	1,059,840	1,920	9.60
Totals	83,970,574	154,656	773.27

This calculation implies a consumption of $\frac{773.27}{8.75}=87.23$ kilos per ton of beets sliced.

Claassen's calculation for the Pauly-Greiner evaporation plant and steam consumption for the working of 100 kilos of beets in one minute.—The following calculation is a very simple one. No claim for absolute accuracy is made, the example being taken from actual practice, and all unnecessary considerations eliminated. Upon general principles, the compartments of an evaporating apparatus should not only be sufficient for the utilization of the vapor from the first compartment in the second, etc., but also for the reheating

of the juice, for graining in the vacuum pan, and they should also be able to evaporate the juice where this vapor is partly cut off.

While a larger volume of juice to be evaporated necessitates an increase in the heating surface of all the compartments of the multiple effect, an increased removal of vapor for the vacuum pan and the juice reheaters, influences mainly the work and the dimension of the compartments from which the vapor is drawn, and also the size of the previous compartments, if there are any. As a general thing, the first compartment and the fore-evaporator are the only ones from which the vapor in question is drawn. It is not necessary to calculate for these the size of heating surface in order to furnish the greatest amount of vapor that is likely to be called for in an emergency. The average vapor consumption is a sufficient guide to determine the size of the heating surfaces under consideration, provided allowance is made for an increase of the pressure of the exhaust steam. As the efficiency of an evaporating compartment increases, within the limits that may be practically considered, about proportionally with the fall of temperature, and as the fall is seldom greater than 6° to 8° C., an increase of 2° to 3° C. (corresponding to an increased pressure of 0.2 atmospheres for the exhaust steam from the machines of the factory that is thus utilized) is sufficient to immediately increase, by one-fourth to one-third, the efficiency of the compartment. This increase is amply sufficient to meet the greatest possible irregularity in steam consumption, either in the vacuum pan or the juice and syrup reheaters.

The multiple effect, as an apparatus, need not be conducted according to cast-iron rules. On the contrary, it can adapt itself rapidly to every condition that may arise. The greatest variations are noticeable in the fall of temperature of the different compartments, and the resulting variations in the coefficient of transmission determine the actual efficiency of the evaporating appliance. All calculations relating to the heating surface should be based upon a given condition of evaporation. Their practical value is not lost even when exceptional factors are introduced. The ease with which the multiple effect adapts itself to special conditions counterbalances in a measure the disadvantages of those unknown factors which are beyond the realm of theory.

It is deemed wise not to adopt for these calculations an excessive temperature of the exhaust steam utilized, and, furthermore, to suppose a very limited fall of temperature in the first compartment, as the heating surfaces of these compartments will then be rather

large in proportion to the work required. These large heating surfaces are important as regards the efficiency of the multiple effect taken as a whole, and its adaptability under the various circumstances that may arise.

The following data are used as a basis for the calculation: Work 100 kilos of beets per minute, i. e., 144 tons per 24 hours, if it were possible to work with absolute regularity. But, as appliances should always have a greater productive power than that of their average working, in order to meet an exceptional emergency (as, for example, when the volume of juice is greater than was intended, and the lime deposits have reduced the heat transmission of the tubes of the multiple effects, etc.), the sizes of the heating surfaces in these calculations are given a practical value for a working capacity of 100 tons per diem. For a larger factory the proportions may be readily obtained by multiplying in a corresponding manner the figures calculated. A drawing-off of 110 kilos of fresh juice from the battery of 120 kilos per 100 kilos of beets is supposed.

The juice is concentrated in the multiple effect from 12° to 60° Brix (6.8° to 33° Bé.), so that 80 per cent, or 96 kilos of water, are evaporated for 100 kilos of beets sliced, and there remain 24 kilos of concentrated juice or syrup. During graining in pan, one obtains from the 24 kilos of syrup 15 kilos of massecuite, which means that 9 kilos of water have been evaporated in the pan. During the graining of the after-products, 1 kilo of water is evaporated for 100 kilos of beets sliced. When using good machines with full admission, the amount of exhaust steam is estimated at 30 kilos per 100 kilos of beets sliced. For the evaporation, a quadruple effect with a fore-evaporator is supposed to be used.

The reheating of diffusion juices is first done in a reheater, with the vapors of the last compartment of the multiple effect at 30° to 50° C., then heated with the vapors from the second compartment to from 50° to 80° C. The vapors from the first compartment are used for graining of the concentrated juice and after-products in pan, also for heating the diffusion, the carbonatation juice, and the syrup.

The first compartment of the quadruple effect is heated with exhaust steam from the machines, and, more heat being needed, it is furnished by the fore-evaporator, in which live steam is used, but in no other apparatus of the beet-sugar factory is live steam resorted to. For reheating, the following quantities of heat are necessary:

1. For diffusion: 110 kilos of diffusion juice from 10° to 30° C. $=110\times 20=2200$ calories; 200 kilos of exhausted cossettes and waste water from 10° to 20° C. $=200\times 10=2000$ calories.

Cooling during diffusion is about 10° C. for 200 kilos capacity of the diffusor for 100 kilos of beets, which corresponds to a heat consumption of $200\times 10=2{,}000$ calories. Consequently the total consumption of heat during diffusion is 6200 calories, equal to 11.7 kilos of vapor from the first compartment of the multiple effect.

2. In reheating diffusion juices in the first reheater with the vapor from the fourth compartment of the multiple effect: $110(50-30)=2200$ calories $=4$ kilos of vapors from the fourth compartment of the multiple effect.

3. For reheating the diffusion juices in the second reheater with the vapors of the second compartment of the multiple effect: $110(80-50)=3300$ calories $=6.1$ kilos of vapor from the second compartment of the multiple effect.

4. For reheating the carbonatation juices from 80° C. to 90° C. and to replace 5° C., representing the losses during cooling: $120(90-80+5)=1800$ calories $=3.4$ kilos of vapor from the first compartment of the multiple effect.

5. For reheating the non-concentrated juice from 90° to 100°, and to replace the 5° C. representing losses during cooling: $120(100-90+5)=1800$ calories $=3.4$ kilos vapor from the first compartment of the multiple effect.

6. For reheating 24 kilos of syrup from 60° to 90° C. (specific heat of the syrup $=0.6$): $24(90-60)0.6=430$ calories $=0.8$ kilos of vapor from the first compartment of the multiple effect.

7. For the graining of concentrated juices or syrups, or the evaporation of 9 kilos water: $9\times 551=4959$ calories $=9.2$ kilos of vapor from the first compartment of the multiple effect.

8. For graining and reheating the after-products, the evaporation of 1 kilo of water and the reheating of 5 kilos after-products: 580 calories $=1.1$ kilos of vapor from the first compartment of the multiple effect.

For graining and reheating, the multiple effect must supply, in the way of vapor:

From the first compartment, $11.7+3.4+3.4+0.8+9.2+1.1=$ 29.6 kilos
From the second compartment . . . . 6.1 kilos
From the fourth compartment . . . . 4.0 kilos

If X is the quantity of water evaporated in the last compartment, there should be evaporated in the first $X+29.6+6.1$; in the second, $X+6.1$; in the third, X kilos; in the fourth, X kilos.

The fore-evaporator should supply as much vapor as the first compartment may require, besides the 30 kilos of exhaust steam, and it should consequently evaporate:

$$X+29.6+6.1-30=X+5.7.$$

The total amount of water that should be evaporated for 100 kilos of beets is 96 kilos. Such being the case, X is calculated by the use of the following formula:

$$96=(X+5.7)+(X+35.7)+(X+6.1)+X+X$$
$$X=9.7.$$

Consequently the total amounts of water evaporated, and caloric transmitted into the different compartments of the evaporating plant, are as shown in the following table:

WATER EVAPORATION AND HEAT TRANSMISSION.

Section of evaporating apparatus.	Water evaporated.	Heat transmitted.
	Kilos.	Calories.
Fore-evaporator.......	15.4	8,162
First compartment.....	45.4	24,060
Second compartment...	15.8	8,532
Third compartment....	9.7	5,305
Fourth compartment...	9.7	5,432
Total..........	96.0	51,491

For this evaporation, and for all graining and reheating purposes, there are needed the following amounts of steam:

	Kilos.
Exhaust steam from engines	30.0
Live steam for fore-evaporator 15.4×1.05......	16.2
Total	46.2

If, instead of the numerous machines with full admission, there are used only a few expansion engines, the quantity of exhaust steam required will be smaller. Under these circumstances one is obliged to use just that much more live steam in the fore-evaporator, and therefore this apparatus becomes most important in factories of modern design.

Besides the 46.2 kilos of vapor for evaporation, reheating, and graining, there is needed:

1. Steam to replace what condenses in the pipes and in the machines on its way from the boilers to the first compartment of the multiple effect. For the full-admission machines, this amounts to about 20 per cent of the exhaust reaching the first compartment, that is to say, 6 kilos.

2. To replace the steam lost through the cooling of the vapors of the multiple effect and vacuum pan, and also the loss through leakage, steaming out the vacuum pans, etc., between 10 to 20 per cent of the total steam used should be added. Consequently there is needed for the heating the following amounts of steam:

	Kilos.
Evaporation, graining, and reheating	46.2
Losses in the machines and pipings	6.0
Other losses	5.2 to 10.4
	57.4–62.6

A beet-sugar factory, when working under the conditions above described, needs 7.5 kilos of coal for 100 kilos of beets sliced, which supposes an evaporation of 8 kilos of water per 1 kilo of coal, or less than 7 kilos when it is possible to evaporate 9 kilos of water with 1 kilo of coal. In German factories the consumption of steam and coal is increased owing to the stoppage on Sunday, which causes an additional one-fourth to one-half per cent of coal.

The quantity of vapors of evaporation to be condensed in a central or separate condenser is 5.6 kilos from the multiple effect and 10 kilos from vacuum pan, or a total of 15.6 kilos.

By applying the principles explained by CLAASSEN, under the caption "Heating Surfaces," the results given in the first table on page 227 are obtained.

As the vacuum pans used for graining concentrated juices or syrups and after-products are not always working, and, as in most cases, the graining is accomplished more or less easily, it is important to allow at least 50 to 100 per cent more heating surface than that determined by calculation. As regards the multiple effects an increase over their theoretical and calculated heating surfaces should be allowed for, especially when the incrustations are not removed at least once a week, or when the juice deposits are in abnormal quantity. There is no need of increasing the heating

surfaces on account of a momentary increase in the working capacity of the plant, for the reason that this fact has already been taken into consideration by supposing that 100 tons instead of 144 tons are being sliced per diem, and the heat transmission coefficients make allowance for this fact.

CLAASSEN'S CALCULATION OF THE HEATING SURFACES FOR WORKING 100 KILOS OF BEETS IN ONE MINUTE, CORRESPONDING TO THE PRACTICAL SLICING OF 100 TONS PER DIEM.

Apparatus.	Caloric transmitted.	Fall of Temperature.	Coefficient of heat transmission.	Heating surface.
	Calories.	° C.		Sq. m.
Fore-evaporator	8160	10	50	16
Evaporator: First compartment	24060	8	45	67
Second compartment	8530	9	30	32
Third compartment	5310	10	20	27
Fourth compartment	5430	17	12	27
First reheater diffusion juices	2200	25	5	18
Second reheater diffusion juices	3300	35	5	20
Reheating carbonatation juices	1800	20	5	18
Reheating filtered juices	1800	10	10	18
Reheating syrups	430	30	5	3
Graining first sugars	4960	30	10	17
Graining after-products	580	30	5	4

To compare the efficiency of the different modes of evaporation, as proposed by the three leading experts mentioned in the foregoing pages, their calculations must be reduced to one standard, as given in the following table.

COMPARISON OF THREE METHODS OF EVAPORATION BY COMPARATIVE DATA.

Authority.	Type of plant.	Temperature of steam for heating.	Vacuum in condenser.	Water evaporated per sq. m. and per hour.	Requisite heating surface 500 tons per diem.	Total steam consumption.
		Deg. C.	Cm.	Kilos.	Sq. m.	Kilos.
DESSIN	Triple effect	111.5	59.5	30	665	172,000
H.-DÉON	Triple effect	112	61	33	600	—
CLAASSEN	Triple effect with fore-evaporator (125° C)	115	57	40	495	* 231,000

* This includes all the steam needed for heating and graining.

The Weibel-Piccard evaporating plant is calculated on the following basis by SVORCIK.[1] It is supposed that the apparatus under consideration is a triple effect, in which the first com-

[1] B. Z., 7, 187, 1883.

partment receives the exhaust steam from the collector and the two other compartments. A portion of the resulting vapors from the first compartment is drawn off by the compressor and forced back into the heating chamber of the same compartment. The juice entering into the first compartment is at a temperature of 75° C., the steam used for heating is at 110° C.—which corresponds to an absolute pressure of 1.41 and a total heat of 640 calories per kilo of steam. In the first compartment the boiling is effected at 94° C.—corresponding to 0.81 absolute pressure and 635.17 calories —and this vapor is compressed at 110° C. The work E to be accomplished by the compressor for one kilo of steam is expressed by the formula

$$E = v.p.\ A \text{ log. nat. } \frac{p}{p'},$$

v = volume of the steam at the absolute pressure of p,

$$p' = 0.81,$$

$$\frac{p}{p'} = 1.74,$$

$$\text{log. nat. } 1.74 = 0.57,$$

A = pressure in kilos per square meter of one atmosphere = 10,334.

Substituting for the letters their equivalents, we have

$$E = 1.25 \times 1.41 \times 10{,}334 \times 0.57 = 10{,}382.$$

$$\text{The theoretical equivalent is } \frac{10{,}382}{424} = 24.48 \text{ calories.}$$

The compression results in adding to the total steam 635.17 calories +24.48 calories = 659.65 calories. But as steam saturated at that temperature and at a tension of 1.41 absolute atmospheres should contain a total heat represented by 640 calories there has resulted a superheating of 659.65 − 640 = 19.65 calories.

To calculate the quantity of water evaporated per kilo of exhaust steam it is supposed that 529 calories may be utilized, and that the condensed water carries off the difference. On the other hand, to evaporate one kilo of water at 94° C. there is needed $606.5 + 0.305 \times 94 - 75 = 560$ calories. One kilo of exhaust steam will evaporate $\frac{529}{560} = 0.9446$ kilos of water in the first compartment which returns to the compressor. One kilo of this vapor will contain $606.5 + 0.305 \times 94 = 635$ calories. Consequently, 0.9446 will contain $635 \times 0.9446 = 600$ calories, the compression will add

$24.48 \times 0.9446 = 23.12$ calories, or a total of $600 + 23.12 = 623.12$ calories. But as 640 calories are needed to evaporate one kilo of water at the absolute pressure of 1.41 atmospheres there is yet needed $640 - 623 = 17$ calories to be supplied by fresh steam. Of the total work to be accomplished during that part of the evaporation the compression will contribute $\frac{23 \times 100}{640} = 3.6$ per cent, and fresh steam that is added to make up for the deficiency, $\frac{17 \times 100}{640} = 2.65$ per cent.

The work E_1 of the compressor for one kilo of steam is calculated as follows:

$$E_1 = v.p.\ A \text{ log. nat. } \frac{p}{p'},$$

v = volume of one kilo of steam in cubic meters = 0.447,
p = 4 absolute atmospheres,
p' = pressure of exhaust steam 1.41 atmospheres,

$$\text{log. nat. } \frac{p}{p'} = 0.834; \text{ consequently,}$$

$$E_1 = 0.447 \times 4 \times 10{,}334 \times 0.834 = 15{,}410 \text{ kg. meters.}$$

It may be concluded that the work of steam in the cylinder of the engine exceeds that of the compressor by $\frac{E_1}{E} = \frac{15{,}410}{10{,}382} = 1.484$.

Therefore, one kilo of steam introduced into the cylinder of the steam engine can compress 1.484 kilos of vapor from the first compartment of the multiple effect to 1.41 absolute atmospheres, or, in other words, it may be said that one kilo of live steam can evaporate, with the assistance of the vapors of the first compartment, 1.484 kilos of water; furthermore, this kilo of live steam will evidently give one kilo of exhaust steam at 1.41 atmospheres, containing 640 calories. One kilo of vapor of the first compartment may evaporate one kilo of water in this same compartment, but as there are lacking 17 calories there will be taken this heat from the exhaust steam for the 1.484 kilos of vapor which the engine will compress with one kilo of live steam or $1.484 \times 17 = 25.23$ calories. Of the 640 calories contained in the kilo of exhaust steam there will still remain $640 - 25.23 = 614.77$ calories, which is equivalent to $\frac{614.77}{640} = 0.96$ kilos of exhaust steam more than is actually needed to conduct the evaporation in the first compart-

ment, combined with the compressor. This exhaust steam must be utilized in one form or another, and it is used in a triple effect in evaporating an additional quantity of water in the first compartment, causing an increase of vapor which helps the evaporation in the other compartments of the apparatus.

The first compartment receives steam at 110° C., boils at 94° C. and its transmission coefficient is 14. The second compartment receives vapor at 94° C., boils at 78° C., and its coefficient is 11. The third compartment receives vapor at 78° C., boils at 62° C., and its coefficient is 9. From what has been said it follows that one kilo of exhaust steam at 1.41 atmospheres absolute pressure may evaporate 0.9446 kilo of water at 94° C. Consequently, 0.96 kilo of exhaust steam can evaporate $0.9446 \times 0.96 = 0.906$ kilo of water in the first compartment; the second compartment will receive 0.906 kilo of vapor at 94° C., which will there evaporate 0.967 kilo of water; and the third compartment receives 0.967 kilo of vapor at 78° C., which will evaporate 0.975 kilo of water. The results of the entire discussion of this subject may be tabulated as follows:

One kilo of live steam will evaporate

1.4 kilos through the means of the compressor,
0.906 kilo through its exhaust steam in the first compartment,
0.967 kilo through its exhaust steam in the second compartment,
0.975 kilo through its exhaust steam in the third compartment,

4.248 kilos of water, total.

The heating surfaces of the different compartments are calculated upon this basis and also upon the heat-transmission coefficients.

CHAPTER XII.

CALCULATIONS RELATING TO VARIOUS PORTIONS OF A MULTIPLE EFFECT.

It is not sufficient that a multiple effect should merely have the requisite heating surface to produce the desired concentration of juice. It is essential that the other elements be arranged for this work, so that all losses of head will be reduced to a minimum. It is important that the juice be properly distributed in each part of the apparatus, and that the evacuation of the vapors and ammoniacal waters be assured and effected with regularity. In other words, the object to be attained in economical evaporation is the greatest fall of temperature and the least possible loss of heat and expenditure of motive force.

The first thing to be considered in a triple effect is the best method of distributing the vapor in the tubular portion of the apparatus, combined with regularity of evacuation of condensed water. In a multiple effect one should endeavor to produce the greatest possible amount of steam, and care for its rapid condensation. This is realized either in the tubular portion of the following compartment, which acts as a surface condenser, or in the condenser at the other end of the apparatus. To obtain a rapid condensation of the vapors or steam it becomes necessary for the connecting pipes to be of considerable size, so that the existing friction may not retard the circulation. This is what occurs in low-pressure machines and has been in a measure utilized in the calculations that follow.

The 320,000 kilos of water to be evaporated in 24 hours (as supposed in the Horsin-Déon plant) equal 13,300 kilos per hour. Consequently, each compartment has to evaporate 4444 kilos of water per hour, or about 1.23 kilos per second. The temperature in different parts of the apparatus is: 112° C. in the exhaust steam collector; 101.25° C. in the first compartment; 86.5° C. in the

second; and 60° C. in the third. Under the corresponding pressures one kilogram of steam will occupy the following spaces:

	Liters.
In the exhaust collector 1200 liters and 1.23 kilos will occupy	1500
First compartment 1630 liters and 1.23 kilos will occupy	2000
Second compartment 2680 liters and 1.23 kilos will occupy	3300
Third compartment 7900 liters and 1.23 kilos will occupy	9700

The calculations which follow apply to the standard type of a triple effect.

The steam-conducting pipes should be calculated, making allowance for the friction created on the angles. The velocity of the moving gases being less than 30 meters, 20 to 26 meters is considered a reasonable limit. In making the calculations the sections of the pipes allowed for should be sufficient for an emergency of extra work. When the quantity of steam produced in a compartment and the section of the pipe connecting it with the next section are known, one may obtain the actual flow by the use of the formula:

$$V=\frac{Q}{s\times m}, \qquad (1)$$

in which Q is the volume in liters of steam escaping per second through the pipes,

s = the section of the pipe in square decimeters,

V = the actual velocity of the flow in decimeters,

m = the coefficient of friction which in this case is about 0.8.

It is supposed that the triple effect under consideration for the working of 4000 hl. has the following general dimensions:

	Meters.
From centre to centre of the compartments	2.50
From third compartment to the centre of sugar arrestor	2.60
Between the first and second compartments and their catch-all	1.80
Between the centre of the connecting pipe to the floor of platform	2.85
From floor of platform to the centre of pump	2.50

Calculation of the pipe connecting the first compartment and exhaust-steam collector.—It may be supposed that the pipe is one meter long and has two bends, and that the valve is constructed so as to produce the same friction as a bend. By using formula (1) we would have for a section of pipe, knowing the volume of vapor

to be 1500 liters and its velocity 25 meters (250 d.m.), the following equations:

$$250=\frac{1500}{s\times 0.8}, \quad s=\frac{1500}{250\times 0.8}=7.50. \quad . \quad . \quad . \quad . \quad (2)$$

Consequently, the diameter = 0.310 m. In order to make allowances for the two bends another formula must be used,[1] by means of which the velocity is obtained, which, instead of 250, becomes 175. The calculation of (2) then is

$$s=\frac{1500}{175\times 0.8}=10.7,$$

and the diameter becomes 0.37.

The diameter of pipe connecting the first and second compartments is calculated in very much the same manner by means of formula (1):

$$250=\frac{2000}{s\times 0.8}; \text{ hence } s=\frac{2000}{250\times 0.8}=10. \quad . \quad . \quad . \quad (3)$$

The diameter becomes 0.357. Then, again, there are two bends which may be considered in one case at right angles, and in the case of the sugar arrestor the bend need not be allowed for at all, owing to its excessive diameter. The ultimate velocity dependent upon these bends is obtained by the use of the formula previously mentioned, and becomes 111.2 instead of 250. By substituting this amount in the calculation the final section is found to be 0.2247, but correction must be made. Previous calculations show that the velocity with which gases flow is inversely proportional to the square root of their density, and consequently if it is admitted that the final velocity of the vapor in the pipe is 25 meters, the velocity in the other pipes should be in the proportion of Vd to Vd', d and d' being the respective densities. In this case

$$\frac{Vd'}{Vd}=0.93.$$

The section, 0.2247, becomes 0.2089, which will give a diameter of 0.515 m., with an initial velocity of $\frac{25}{0.93}=26.8$ m.

By continuing the argument for the second compartment one finds that the initial velocity of the vapor is equal to 32 m., and in the third, connecting with the condenser, 50 m. At such velocities

[1] This formula is too complicated for use in the present writing.

the losses through friction, etc., need not be considered. When the calculations are repeated, as in the foregoing for the second and third compartments, the diameters of the pipes will be found to be 560 and 800 mm. If no allowance had been made for the bend in the pipes their diameter would have been only 700. In case a triple effect is to be heated by direct steam, the steam pipe calculated according to the rules in question would have a section of $s=0.0260$ sq. m. and a diameter of 0.18 m. DESSIN, on the other hand, introduces many other elements, and adopts many lower coefficients to make allowances for loss of head due to friction against the sides of the pipes.

In his previous calculations a fall of temperature of 12.5° C. was admitted for each compartment. As there is a flow of steam from the upper part of one section toward the tubular cluster of the following one, there must necessarily be a difference of pressure between the two, which means a difference of temperature. This may be admitted to be 0.5 C., and it may be demonstrated that the existing difference of pressure is sufficient to force the flow, provided, however, that the section of the pipes through which it circulates does not for one reason or another become reduced. This would result in an abnormal velocity of the steam. To determine the velocity corresponding to 0.5° C., supposing that the vapor leaves the first compartment at 97.5° C., or 0.954 atmosphere absolute pressure, its temperature upon reaching the second compartment is 97° C. and the pressure causing the flow is

$$0.954-0.930=0.024 \text{ of an atmosphere,}$$

or that of a column of water 0.24 meter high. The formula expressing the rapidity of flow of gas and watery vapors through an orifice is too complicated for the present writing. Simplified, it becomes $V=\sqrt{2gE}$, in which E is the column of water representing the difference of pressure or head resulting in the flow. In the case under consideration it is 0.24 meter, and the velocity is then found to be $V=66$ meters.

The actual velocity does not approach this, and to make allowance for the error certain coefficients must be adopted, which again leads to very complicated calculations. Approximately, 0.50 may be taken as the total coefficient, and the velocity of flow from one compartment to another is admitted to be 33 meters. If the same arguments and calculations were applied to the steam pipes it would be found that the exhaust steam enters the first com-

partment at a slightly higher velocity, while that of the vapors upon reaching the third compartment is a little less. Consequently, from a practical standpoint, a velocity of 30 meters per second may be considered as an average. Upon leaving the third compartment, however, in order to avoid an exaggerated section for this pipe, the vapors are allowed to attain a velocity of 50 meters per second, as the loss of temperature is not any longer an objection.

Dessin's calculation of exhaust-steam pipe.—Upon the basis mentioned in the foregoing paragraph it is possible to calculate the section of the pipe that brings the steam from the exhaust-steam collector to the first compartment of the multiple effect. The weight of exhaust steam per second entering the first compartment at a temperature of 111.5° is, in DESSIN's example,

$$\frac{76,950}{24\times60\times60}=0.89 \text{ kilos.}$$

As a kilo of this vapor occupies a volume of 1.16 cb. m., the volume of vapor per second entering the first compartment will be

$$0.89\times1.16=1.0324 \text{ cb. m.}$$

At 30 meters velocity the section of the valve where the steam is taken will be

$$\frac{1.0324}{30}=0.0344 \text{ sq. m.,}$$

requiring a diameter of about 210 mm., or, in round numbers, 13.5 sq. mm. per hectoliter of juice handled. The volume of the vapor per second entering at 97° C. into the second compartment is

$$\frac{216,000}{3\times24\times60\times60}\times1820=1.5114 \text{ cb. m.}$$

At 30 meters velocity the section of the pipe connecting the first and second compartments will be

$$\frac{1.5142}{30}=0.0505 \text{ sq. m.,}$$

or a diameter approximately of 260 mm., corresponding to an area of 19.8 sq. mm. per hectoliter of juice. The volume of vapor per second entering the drum of the third compartment at 80° C. is

$$\frac{216,000}{3\times24\times60\times60}\times3.44=2.8620 \text{ cb. m.}$$

At 30 meters velocity per second the section of the pipe connecting the second and third compartments will be

$$\frac{2.8620}{30}=0.0954 \text{ sq. m.},$$

or a diameter approximately of 350 mm., corresponding to an area of 37.4 sq. mm. per hectoliter of juice. The volume of vapor per second leaving the third compartment at 58° C. is

$$\frac{216,000}{3\times 24\times 60\times 60}\times 8.47=7.0470 \text{ cb. m.}$$

At 50 meters velocity the section of the pipe through which this vapor escapes will be

$$\frac{7.0470}{50}=0.140 \text{ sq. m.},$$

or a diameter of 420 mm., corresponding to an area of 54.8 sq. mm. Calculations of very much the same kind may be made for the determination of the sections of the pipes of multiple effects, consisting of more than three compartments, velocities of 30 meters per second for the connecting pipes, and 50 meters per second for the exit to the condenser being supposed for these cases.

The calculations of the section of the pipes for the juice and condensed water have not the same importance as those just mentioned. It is very important, however, that they should be sufficiently large to do the work required of them.

Horsin-Déon's calculations relating to the feed pipe of a triple effect are of interest. The juice should circulate in the pipe at a maximum velocity of about 3 meters per second, and as all the juice must pass through it there will be a flow of 4.63 liters per second. The diameter of the pipe may be found from the formula previously given, viz:

$$Q=\frac{\pi D^2 Kv}{4},$$

in which the coefficient K is about the equal to 0.6. By substitution the equation becomes

$$4.63=\frac{\pi D^2\times 0.6\times 3}{4}.$$

Therefore, $s=0.057$ m. and $D=0.180$ m.

In this case there need be no apprehension regarding the use of a pipe of excessive dimensions, as the entrance of the juice into

the apparatus is regulated by a pump or valve cock. The other juice pipes may have the same or a smaller diameter. Those for the exhaust, ammoniacal vapors, etc., may be calculated in very much the same manner. It is needless to elaborate the subject further, but it is interesting to note that steam pipes should be large enough, proportionately, to compensate for friction, etc., and to prevent the absorption of a portion of the motive power.

Dessin's calculation of the section of the condensed water pipes, and size of the ammoniacal water pumps.—The section of the pipes for condensed water may readily be determined. For a triple effect with 300 square meters heating surface, certain elements of which have already been calculated, the water to be extracted from the first compartment has already been shown to be 0.89 kilos per second; and if we admit, as is customary, an average flow of 0.50 meters per second, the section for the pipe will be

$$\frac{0.89}{5} = 0.178 \text{ sq. dm.}$$

This corresponds to an interior diameter of 48 mm., which in practice would be 55 to 60 mm.

The suction pipes for the ammoniacal water may be calculated like those for the condensed water of the first compartment. The amount of water to be extracted from the last two compartments is, for a triple effect of 300 square meters heating surface,

$$\frac{216{,}000}{3\times24\times60\times60} = 0.83 \text{ liters per second.}$$

If the velocity of circulation is 0.50, it would require a section of

$$\frac{0.83}{5} = 0.166 \text{ sq. dm.,}$$

corresponding to a diameter of 46 mm. This would be suitable for a continuous flow; but when the pump works during one-half stroke, to retain the velocity of 0.50 m. per second, it becomes necessary to double its capacity, and the interior diameter of the pipe should consequently be practically 75 mm.

The calculations relating to the most desirable sizes for ammoniacal water pumps, the stroke and velocity of which correspond to those of the air pump, to which it is generally connected,

are as follows: In the case under consideration the pump should remove per minute

$$2 \times 0.83 \times 60 = 996 \text{ liters of water.}$$

Under the conditions of its working, the efficiency is not more than 60 per cent, and the pump should give a volume of 1.810 liters per minute to meet the requirements. This permits the determination of the diameter of the pump and the length of stroke, the number of strokes being determined in advance.

Arrangements for ordinary condensers.—Generally these appliances are entirely too small. The phenomenon, considered theoretically, should be instantaneous. This condensation results in at once liberating the gas and the air that will not condense, the volume of which represents more than a hectoliter per kilo of vapor. It stands to reason that, if the capacity of the condenser is not sufficient to contain the free gas and the new vapor to be condensed, as the efficiency of the pump is checked when passing over the dead points, these gases will momentarily offer an obstruction to the condensing action of the water. This difficulty is very apparent, because the vapor has a very low density. For this reason it is customary to give to the condensers a minimum capacity equal to four or six times that engendered by the piston of the air pump during one-half stroke.

Horsin-Déon's views on condensers.—The capacity of the condenser should be sufficient for the water spray to develop, and for the velocity of the vapor upon entering the appliance to be retarded. Furthermore, the water should produce its maximum cooling effect upon the inert gases. The diameter of the condenser should be greater than that of the connecting pipe, but it is very difficult to determine its capacity. In steam engines it is frequently equal to a quarter of the volume of the cylinder of the motor; and if this proportion is adopted, the condenser will have a capacity equal to one-quarter of the volume of the vapor to be condensed per second. In the third compartment there are 9700 liters of vapors to be condensed per second. If the condensing cylinder has a diameter of one meter, its height would be 1.272 meters for one cubic meter capacity, and into this cylinder the 30 liters of water are injected.

Large condensers are recommended, for the reason that the injected water generally contains air in solution in quantities representing one-twentieth of its volume; and if a calcareous water is used, a certain volume of carbonic acid is liberated under the influence of

the vacuum and the heat. Making allowance for these facts, 30 liters of water will contain about 1.5 liters of air at the atmospheric pressure, and, at a pressure of 1/8.6 atmospheres, 1.5×8.6, or 12.90 liters. The dilatation of this air corresponds to that of the vapor entering the condenser. The volume becomes about 15 liters in making allowance for the temperature, or one-half that of the water from which it arises. Furthermore, in all appliances ammoniacal vapors are evolved, to which may be added the air from the juice itself and the air entering through leaks, giving a total of 30 liters of non-condensable vapor introduced into the condenser per second. As a general thing, condensers have a capacity of 300 liters, the water and the non-condensable vapors occupying a volume of 60 liters, or one-fifth of the total. If the capacity of the condenser were 1000 liters, the non-condensable vapors would be distributed over an area three times greater, and their pernicious influence upon the condensation would be one-third as great. The whole question of the volume of a condenser is based upon many empirical considerations, but upon general principles it should be as large as possible, and at least three times greater than that of the air pump.

Quantity of water to be injected.—The volume of water necessary to be injected, in order to condense the vapor formed in a triple effect, is calculated by the following formula (MORIN):

$$P=\frac{p(550+T-T')}{T'-T''}.$$

P represents the weight of the water necessary for the condensation;
p represents the weight of vapor to be condensed;
T, the temperature of the vapor to be condensed;
T', the temperature of the water leaving the condenser;
T'', the temperature of the water injected.

In a triple effect of 4000 hl. (the same as the one considered by HORSIN-DÉON in his original calculation),

$$p=1.23 \text{ kilos}, \quad T=60^\circ \text{ C.}, \quad T'=55^\circ \text{ C.}, \quad T''=10^\circ \text{ C.}$$

$$P=\frac{1.23(550+60-55)}{55-10}=15.17.$$

This is a minimum quantity. In DESSIN's calculations the letters have the following significance:

$T=58^\circ$ C. = temperature of vapor to be condensed;
T', the temperature of the products of condensation, is equal to 40° C.;
T'', the temperature of the injected water, 15° C.

Replacing the letters by their equivalents, the equation becomes

$$\frac{550+58-40}{40-15}=22.7 \text{ liters.}$$

That is, the condensation of one kilo of steam flowing from the third compartment of a triple effect demands theoretically 22.7 liters of water, or about 30 liters, making allowance for unknown factors.

JELINEK[1] states that, at the beginning of the sugar campaign, the conditions are expressed by the formula:

$$\frac{550+60-35}{35-20}=38 \text{ liters.}$$

He says, however, that an average of 30 liters may be considered.

The pipe conducting the injected water into the condenser should have a diameter that will allow the spray obtained to reach the top of the condenser. HORSIN-DÉON uses for the calculation the following formula:

$$Q=KSv=\frac{\pi D^2}{4}Kv.$$

Q = the effective expenditure through the opening of the pipe;
S = the section of the pipe;
D = the diameter of the pipe in decimeters;
v = the average velocity of the liquid;
K = the coefficient of expenditure of water delivered.

The coefficient, K, depends upon the pressure of the liquid and the diameter of the pipe, which value may be obtained from specially arranged tables; therefore,

$$30=\frac{\pi D^2}{4}\times Kv.$$

But $v=V2gh\frac{d}{d'}$, and h equals 10 meters, corresponding to the barometric column reduced by the distance from the condenser to the surface of the water in the well. If that height is 5 meters, then h is also 5 meters, and, as $d'=1$, we have $V=36.5$: if $K=0.60$, $30=\frac{\pi D^2}{4}\times 0.60\times 36.5$, from which it is concluded that $D=0.153$ m.

[1] JELINEK, Verdampfapp., 98, 1886.

and $S=0.018385$ sq. m. The section of the spraying or injection device should be about the same as that of the pipe itself, owing to the contraction of the liquid vein, which has an influence on Q that may be represented by a coefficient very like that of K. The section of the pipe where the injection takes place should be a fraction larger than the pipe conducting the water, so as to diminish the loss caused by friction, etc., during its passage through the turns and bends of the pipe. Under these conditions the water readily passes into the injecting apparatus.

In the calculations of DESSIN the head of the flow is somewhat different. The following conclusions are reached, based upon the plant previously considered. The section of the pipe used for the injected water is calculated from the volume to be introduced and the velocity of water in the pipe, the latter being deducted from the formula $V=\sqrt{2gh}$, to which must be applied a special coefficient making allowance for the contraction of the vein. This may be supposed to be 0.60 to 0.65. In the formula, h represents the height of water in meters to produce the flow, and is evidently equivalent to the vacuum existing in the condensers, diminished by the height of the suction and the losses of head due to the length of the injecting pipe, which in many cases is considerable. With a triple effect having 300 square meters heating surface, the volume of water to be injected into the condensers is 25 liters, according to previous calculations. The vacuum is supposed to be at 66 cm. of mercury, which corresponds to a column of 9.5 meters of water. Supposing that the water is to be raised to a height of 4 meters, and that, owing to the length of the pipe, the losses of head, calculated on an approximate basis, are represented by 2.5 meters, the charge tending to produce the flow will be

$$9.5-(4+2.5)=3 \text{ meters.}$$

The velocity of the flow will be $V=0.60\sqrt{2\times 9.81\times 3}=4.60$ meters. The section of the injecting cock should then be $\frac{25}{46}=0.54$ square decimeters. This supposes a diameter of 83 mm., and, to make allowances for all possible obstructions, it may be called 95 mm.

It must be understood that the data cannot be taken too literally, and, wherever the pipe conducting the water used for injection is of an exceptional length, the calculations should be modified accordingly.

Calculations relating to dry- and moist-air pumps.—Whatever be the design of the pump, it should have a minimum of dead spaces. At the instant when the piston has reached the end of its stroke, the dead spaces (estimated at 4 per cent) are filled with compressed gases at the atmospheric pressure. The piston, upon resuming the stroke, can commence its suction only when the gases in question have expanded to the effective pressure existing in the condenser; that is to say, at 0.0722 atmospheres in the case of a 66 cm. vacuo. According to the Mariotte law, this tension can be realized only when the volume behind the piston is

$$\frac{1\times 0.04}{0.0722}=0.55,$$

that engendered by the piston being represented by 1; in other words, when the piston has travelled,

$$0.55-0.04=0.51,$$

or fifty-one one-hundredths of its stroke. In moist-air pumps, the dead spaces are generally filled with water, and the dead spaces have not the same importance as in dry-air pumps.

Size of moist-air pumps.—The moist-air pump has not been sufficiently studied in most countries where beet-sugar is made. Dessin pointed out some years ago that its dead spaces corresponded to a volume equal to two or three times the volume engendered by the piston during one-half stroke, and this means an efficiency of only 60 per cent of what is called for in theory.

The air pump must draw from the triple effect,—

1. The condensed vapor from the third compartment.
2. The water injected.
3. The expanded vapor from the second and third compartments, supposing that there is no special pump.
4. The air contained in the injected water, or one-twentieth of the water.
5. The air contained in the juice to be evaporated, or one-twentieth of the juice.
6. The air contained in the three compartments and the condenser when empty.

Furthermore, as the vapors of the apparatus contain incondensable gases, air, carbonic acid, etc., certain difficulties arise during condensation. The quantity of non-condensable gases has been very differently estimated by the leading experts. According

to Horsin-Déon, the juices lose 0.0112 kilos of nitrogen through the proteids and 0.0062 by the ammoniacal salts during evaporation, which means 0.023 kilos of ammonia per 100 kilos of juice. This ammonia returns to the condenser. The 4.8 kilos of juice evaporated per second lose consequently 1.104 grams of ammonia, or about 10 liters, which volume should be doubled in making allowance for inferior beets, and, calculating on a very general basis, it may amount to 20 liters.

Air enters abundantly through leaks, around the look-glasses, through the cocks, and by the juice pump, and, taken collectively, may be estimated as one-fourth per cent of the condensed vapors, or $\frac{0.25}{100}$ of 9.700, amounting to 24.25, or about 25 liters.

A statement of the water, air, and vapors present is as follows:

	Liters.
1. Condensed watery vapor in the third compartment	1.23
2. Injected water	30.00
3. Air contained in the water injected	15.00
4. Air of the total juice, one-twentieth of 46.3	2.30
5. Ammoniacal vapors	20.00
6. Air entering through leaks	25.00
Total	93.53

Attention is called to the fact that a pump that would develop so small a volume would be of very little assistance in obtaining the necessary vacuo. A frequently accepted rule for an air pump is, that it should have a cylinder with an active volume corresponding to eight times that of the water injected. If this statement is adopted, the volume developed by the pump would be 260 liters per second. If the pump makes forty strokes, it should have a volume of 340 liters. This is larger than is usual in French multiple effects. It is not customary to exceed 300 liters with pumps of a 0.7 m. diameter and a stroke of 0.8 m. Horsin-Déon calls attention to the great variance in the size of the pumps in actual use, and points out that for a triple effect the volume should be from 11 to 14 times that of the water injected per second, and that the reason so limited a vacuum is frequently obtained in triple effects is, that the pump is too small by one-half.

Dessin's calculation is very much the same as the foregoing. He supposes that the vacuum existing in the apparatus is about

66 cm., corresponding to an absolute pressure of 0.0722 atmospheres at a temperature of 40° C. At that temperature also the condensed waters leave the air pump. Air and other non-condensable gases are brought to that temperature, and occupy a volume that depends upon that temperature and the vacuum. They should be allowed for, but this would complicate the calculation without giving it more accuracy, as the amount of these gases can only be estimated.

Under the conditions just mentioned, one kilo of vapor at 40° C. will occupy a volume of 19,700 liters. The total volume to be extracted from the condenser with injector, per kilo of condensed vapor, by the use of a moist-air pump, is as follows:

	Liters.
1. Volume of condensed vapor leaving third compartment.	1.0
2. Volume of injected water necessary for the condensation of this kilo of vapor.	30.0
3. Volume of air in solution in the juice when introduced into the apparatus and equal to one-twentieth of its volume, or $\frac{3.6}{20}=0.18$ liters, becomes, upon its reaching the injecting condenser, where the absolute pressure is only 0.0722 atmospheres, and where it expands, according to Mariotte's law, $\frac{0.18}{0.0722}=$	2.5
4. Volume of air in solution in the injected water, representing one-twentieth of its volume, or $\frac{30}{20}=1.5$ liters, when expanded in the condenser, become $\frac{1.5}{0.0722}$	20.7
5. Volume of ammoniacal gases, the outcome of the decomposition of organic substances contained in the juices, etc. To allow for this quantity it is admitted to be approximately .05 per cent of the volume of vapor to be condensed, which in this case will be $\frac{0.5\times 19.700}{100}$	$=98.5$

The total volume to be removed from the condenser per kilo of condensed vapor is 152.7 liters. If 0.55 is adopted as a coefficient of efficiency for the moist-air pump, the volume engendered by the air piston for one kilo of vapor to be condensed may be deducted,

$$\frac{152.7}{0.55}=277.64 \text{ liters},$$

or, in round numbers, 280 liters. If we again consider the triple effect of 300 square meters heating surface, and admit that from

its third compartment there leave

$$\frac{216,000}{3\times24\times60}=50 \text{ kilos per minute,}$$

the volume engendered during the same interval by the air pump, in connection with it, should be at least

$$50\times280=14,000 \text{ liters.}$$

This calls for a pump of 0.53 m. in diameter and 0.6 m. stroke. In this problem, one of the most difficult factors to make allowance for is the air that penetrates through leaks; hence the importance of making a practical test of a triple effect with its air pump, etc., before filling with juice. It must not be forgotten that one liter of air at atmospheric pressure becomes 14 liters when entering the condenser.

Calculation of the size of dry-air pumps.—DESSIN states that in the dry-air pumps the practical sucking efficiency is 88 to 90 per cent of the theoretical volume engendered by the piston; hence the practical efficiency may be conceded to be 80 to 85 per cent.[1]

The calculation of a dry-air pump offers no difficulty. The calculations made for the moist-air pump, previously given in total, must be considered. It may be concluded that the volume of incondensable gases to be extracted from the barometric condenser per kilogram of condensed steam is made up as follows:

	Liters.
1. Volume of air in the juice upon entering the apparatus and expanded in the condenser	2.5
2. Volume of air in the water of injection and expanded in the condenser	20.7
3. Volume of ammoniacal gases removed by the barometric condenser	98.5
Total	121.7

If the figures 0.8 be taken as the efficiency coefficient of the dry-air pump, it may be concluded that the volume engendered by the piston of this pump per kilo of condensed vapor should be

$$\frac{121.70}{0.80}=152.12 \text{ liters,}$$

or, in round numbers, 160 liters. In a triple effect of 300 sq. in. heating surface, from which 50 kilos of steam leave the third com-

[1] The improved air pumps made of late have often an efficiency of 95 per cent, and even more.

partment per minute, there will be needed a dry-air pump that may handle a volume of $50 \times 160 = 8000$ liters during the same interval. This supposes a dry-air pump of 0.38 m. in diameter, with a stroke of 0.4 m., and working at a velocity of 90 revolutions per minute.

In the previous calculation for a moist-air pump, it was shown that the piston had a diameter of 0.55 m. and a stroke of 0.60 m., that is to say, it was very much larger than in the case of the dry-air apparatus. The size of the water-injecting pump is calculated by supposing 30 liters of water per kilo of vapor to be condensed as a minimum. To calculate the size and extent of the cooling plant, numerous factors difficult to estimate must be considered. It would be necessary in the arguments to enter into the question of energy expended through the working of various condensing appliances, as local conditions play an important rôle. For example, in one factory the water of injection is pumped from a certain depth, in other cases the condensed water from the injectors is cooled to be used over again, and each of these cases demands special calculations.

PART V.

MANUFACTURE OF RAW SUGAR.

CHAPTER I.

GRAINING.

Historical and generalities.—For commercial and technical reasons the thick syrup from a multiple effect, containing sugar, must undergo further manipulations that will permit the product to be obtained in a crystalline form. This operation is known as graining, and consists in eliminating the water until a degree of concentration is reached which is followed by crystallization. The latter phenomenon will be explained under another heading. The graining, properly speaking, is preceded by evaporation up to a saturation point, at which moment more syrup is introduced into the massecuite being formed. It is to be noted that this evaporation could not be accomplished in a multiple effect, because the temperatures vary with the syrups themselves; furthermore, the crystallization has to be conducted at a comparatively high temperature, and the operation of graining from start to finish is too irregular in its working to form a part of the evaporation, hence it is effected in special appliances.

For a long period of years the final concentration of syrups took place in open receptacles, and did not essentially differ from the evaporation proper. In Continental Europe, even as late as 1880, there were some beet-sugar factories still working by that primitive method. The first methods to control the progression of the operation of concentration were introduced by GUYTON DE MORVEAU, in 1774, with the use of the areometer; then followed DUTRÔNE, in 1790, with the thermometer. Under the caption of Evaporation,

it has already been pointed out that HOWARD, in 1813, introduced appliances for graining and evaporating in vacuo, from which idea originated all the modern apparatus having the same object.

Concentrated juices or syrups from the last compartment of a multiple effect are grained in a vacuum pan, where the juices are concentrated and the sugar crystallized. The apparatus should be fitted to these two operations, thus giving a superior crystallization of sugar. Generally, vacuum pans have very much the same shape and installation as the compartment of the multiple effects, with, however, the modifications essential for the concentration of the viscous mass and the final pasty product. Usually preference is given to the vertical type with conical bottom.

A general view of the now obsolete vacuum pan is shown herewith (Fig. 115). Several observation lenses of thick glass permit a view

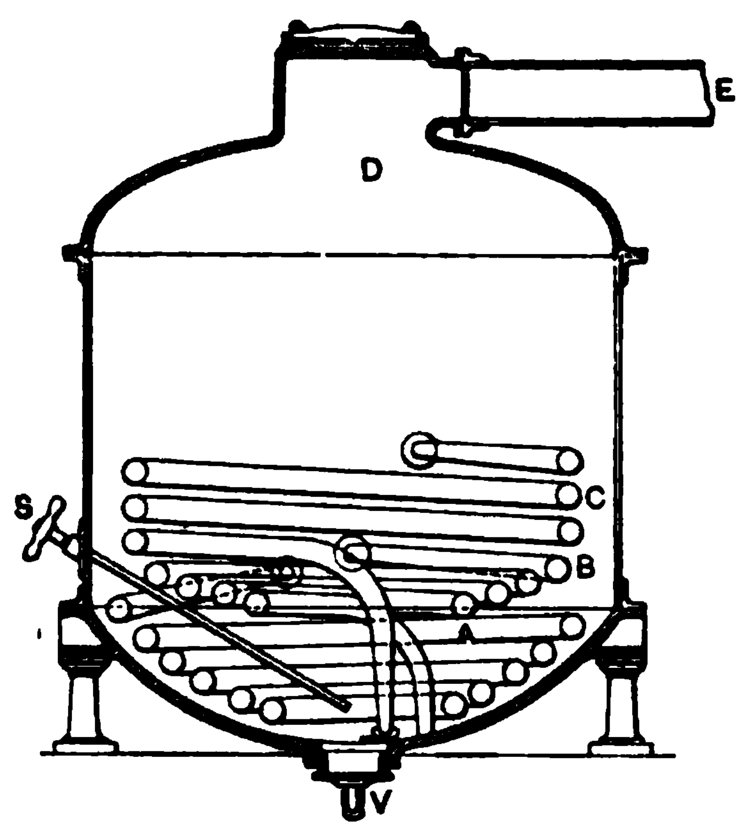

FIG. 115.—Old-style Vacuum Pan.

of the interior, so that the progress of the cooking may be closely watched. Samples of the syrup may be examined by withdrawing a bronze test stick, *S*. The vacuum pan may be emptied by opening a large valve *V* placed at the bottom. The exhaust pipe, *E*, for air and vapors during cooking, is placed on the upper part, *D*, and the apparatus is properly covered with wood or other non-conducting material. The apparatus is heated by three coils, *A*, *B*, and *C*, which may be separately or collectively worked, depending upon the progress of the graining.

Vacuum pans at first were almost entirely made of copper, but in 1880 iron pans became popular, and after that time their shape underwent a few changes. Instead of being spherical they

were made cylindrical; this shape is more easily constructed, costs less, and, furthermore, the exterior surface is more readily covered with some non-conducting material.

Size of vacuum pan.—The working capacity of a pan depends upon the work to be accomplished, but very seldom exceeds 500 hl. In California[1] gigantic pans were introduced many years ago. These apparatus could give in a single strike 175,000 kilos of massecuite. They were 14 meters high, and had a diameter of 5.5 meters.

Upon general principles, it may be said that the running of a large pan always means an economy of labor—there are, nevertheless, numerous objectionable features not to be overlooked. If we suppose a density of 1.5 for the massecuite just before the strike is completed, the steam bubbles liberated on the surface of the coils, in order to escape, must overcome an atmospheric pressure before they will be under the same conditions as those boiling on the surface of the mass. There necessarily results an exceptionally high temperature in the lower stratas of the product being grained, and this it is always most desirable to obviate.

On the other hand, it is not advantageous for the working of the factory, especially for the multiple effect, to have only one vacuum pan for the graining of the syrups. When starting this pan considerably more vapor of evaporation is demanded than the multiple effect or the fore-evaporator can supply. As the graining in pan progresses the volume of concentrated juice drawn from the last compartment of the multiple effect diminishes, the vapor consumed is lessened, and at the end there is none used at all, so that the juice accumulates in the evaporating apparatus. Every beet-sugar factory should consequently possess at least two vacuum pans of suitable size, and work them alternately in order to draw off the concentrated juice and utilize the vapors from the multiple effect regularly.

The use of a large vacuum pan is not economical, for direct steam must be used at the end of the strike. As the graining in this case lasts for a considerable period, the caramelization of the product being worked and the viscosity increase and the mass undergoes the preliminary stages of inversion. The subsequent working of the massecuite in the centrifugal is rendered more difficult. In the case of very large pans the time needed to complete the strike is necessarily very great, and the work has to be done by several

[1] Oe.-U. Z., 17, 761, 1888.

sugar boilers, which also has objectionable features. Large pans do not give better sugar than the small ones, nor are the after-products better. As the large pans remain idle for several hours during the day they necessarily cool during this period, and this loss of caloric is an important item not to be overlooked. Another important item is that large pans are more expensive than small ones, and this extra outlay does not give an equivalent practical return. It is now generally admitted that a comparatively small pan will give a greater amount of work per unit of heating surface than will a larger pan, provided the mass is kept in constant motion.

The size of a vacuum pan depends mainly upon the period the graining is to last. It is very important to have waiting tanks for a certain quantity of syrup, so as to be able to meet any emergency that may present itself, and thus prevent irregularity in the general working. MALANDER points out that this reserve should never exceed the amount needed for two hours' graining; otherwise, the syrup would cool and there would be danger of fermentations. LOEBLICH,[1] discussing the size of a vacuum pan, maintains that it has an important influence upon the time necessary to complete a strike. In the old types of pan of five meters diameter the operation was completed in two hours less time than in the newer shapes. Experience seems to prove that there are numerous advantages in having the graining finished and the pan emptied in about ten hours, that is, counting from the time the first granulation manifests itself. On the other hand, in certain beet-sugar factories the strike is completed in five hours and even less, but this practice necessarily materially reduces the size of the resulting crystals.

Heating surfaces.—The heating surface of vertical pans sometimes consists of several spiral steam coils placed one over the other, or one interwoven with another; or, again, tubes are arranged in the form of a lyre. The standard tubular clusters of vertical and horizontal evaporators are used also.

Red copper is generally used for making the coils, owing to the facility of shaping it, which is an important factor when the problem is to obtain considerable heating surface in a small space. The heating tubes are, however, frequently made of iron, which possesses the advantage over copper and brass that it is not readily attacked by ammoniacal gases. The disadvantage such tubes offer

[1] D. Z. I., 24, 516, 1899.

in a multiple effect is their low coefficient of heat transmission, which, in the case of a vacuum pan, is of secondary importance. CLAASSEN says that in vacuum pans the ammoniacal gases have a

FIG. 116.—GREINER'S Heating Surface, General Arrangement.

more active effect upon the heating tubes than in the multiple effects, for the reason that the velocity of the vapor or steam used for heating is very small, and, consequently, the ammoniacal gases have ample time to exert their action by collecting in certain places.

With the view to the better utilization of the steam and to obtain a nearly constant coefficient of transmission for all the

FIG. 117.—One Series of Coils.

heating surface, HALLSTROEM[1] proposed to make the coils of constantly decreasing diameters, from the entrance to the exit of the steam, or where the condensed water leaves the apparatus.

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[1] Oe.-U. Z., 14, 94, 1885.

Certain difficulties necessarily arise, one of which is that the heating efficiency of a tube decreases with its size, which demands, all facts taken into consideration, that its length be increased in order to equalize the disadvantage of small diameter. Then there follows a greater friction of the circulating steam and

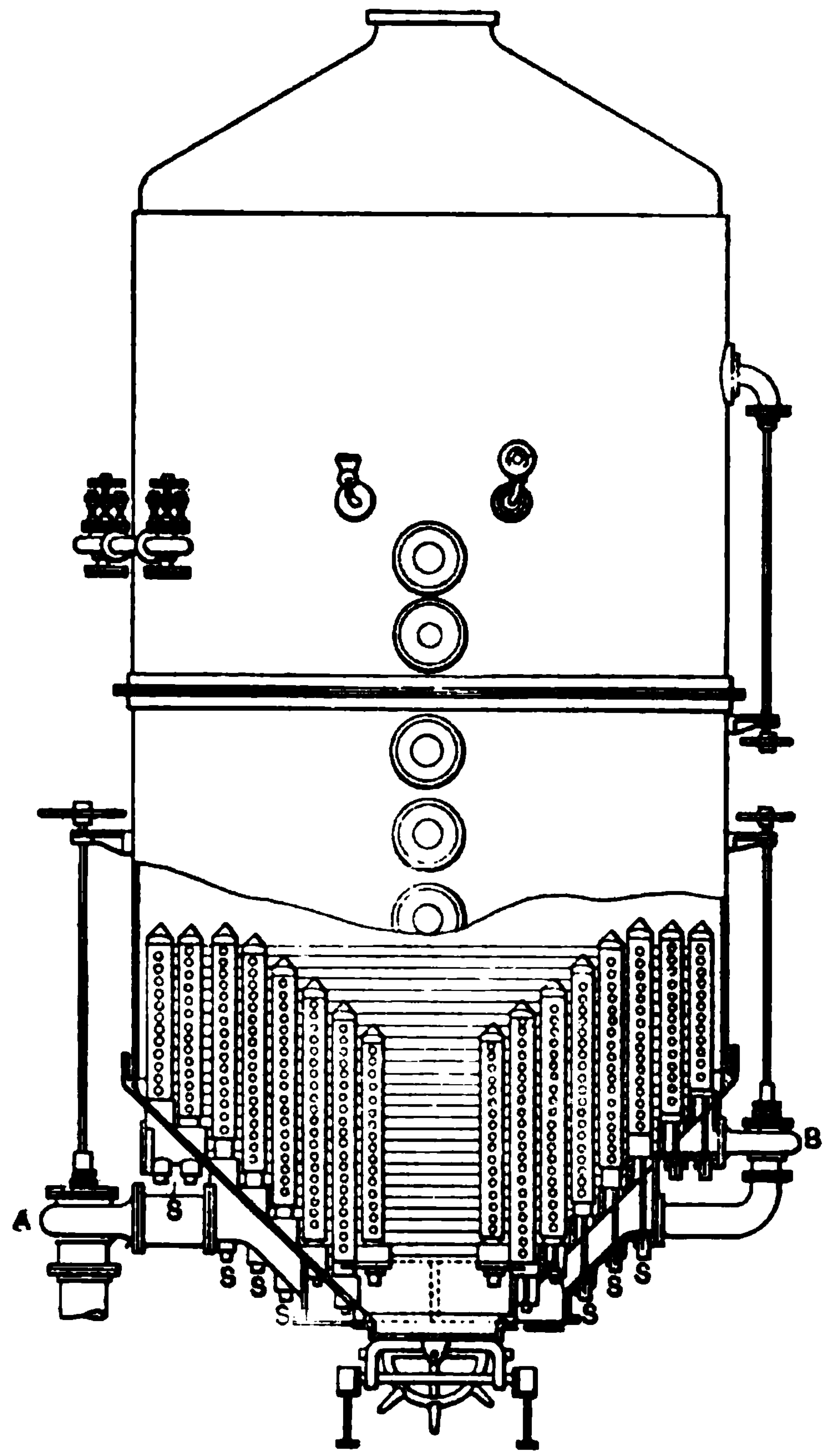

FIG. 118.—GREINER Vertical Pan.

condensed water, which necessarily means loss of head. The problem, however, has been solved in two different ways. The heating surface of the GREINER vacuum pan consists of coils combined so that they have a cylindrical-conical appearance (Fig. 116), though they form in reality a series of concentric tubular crowns (Fig. 117), made up of tubes all centred upon hollow cast-iron supports, *Sd* and *Sw*, to which the steam is distributed through the large pipe, *R*.

The condensed water runs off from the lower part of the hollow columns into the pipe, W.

As this arrangement necessarily involves certain difficulties in mounting and unmounting in making repairs, etc., GREINER has introduced several important changes (Fig. 118). The entrance and exit

FIG. 119.—CAIL Vacuum Pan, Elevation.

of the steam is at the bottom of the apparatus. It enters one side at A, and then flows through the series of small crowns which are used at the beginning of the graining. Toward the end of the operation, when it becomes necessary to raise the temperature for additional heating, the valve, B, is opened and the steam then circulates in the last two coils. The coils are very readily taken

apart. When they need unmounting, in case of repairs, the nuts, *s*, are simply unscrewed and the crown is lifted in the interior of the apparatus. The arrangement is such that there are no movable parts in the interior of the pan, such as nuts, etc., to become loose and cause subsequent trouble during the work.

The RASSMUS combination (Figs. 119 and 120) makes possible an enormous heating surface in a very small space. The tubes are arranged in the shape of a lyre, and the two extremities of each pipe open into boxes intended either to receive the steam or for the escape of the condensed water. The CAIL construction of this apparatus is very interesting. It contains at the bottom two coils in which the graining is commenced. The lyre arrangement is in clusters of six in the same horizontal plane, and the eighteen planes are arranged in three distinct clusters. One of the extremities of these steel heating tubes of 50 mm. is adjusted to a box for the reception of steam and the other to one intended for the exit of the condensed water, as previously pointed out. The ends of these pipes are bent in such a way as to enter the steam box under the most favorable conditions. Precautionary measures are taken to have all the pipes firmly held so that they will not become displaced during graining. The spacing between them is amply sufficient for the easy escape of the massecuite. There are three steam boxes placed one over the other, but entirely separated, so as to allow the possibility of heating up one independent of the others, as the operation progresses. Vacuum pans have also been constructed with an outer appearance almost identical with one of the compartments of a multiple effect.

FIG. 120.—CAIL Vacuum Pan, Plan.

WERNICKE[1] (Fig. 121) recently patented a pan that has vertical tubes attached to two spherical disks, the central portions of which slant downward. This shape facilitates the running off through a

[1] Z., 52, 895, 1902.

central pipe of the massecuite, even when the graining has been unusually tight. The apparatus may be constructed with an exceptional heating surface. HAACKE's[1] pan is of very much the same arrangement, with the difference, however, that the tubular portion is suspended in the centre of the apparatus, the tubular plates are conical instead of spherical, and there is ample space for the massecuite to circulate.

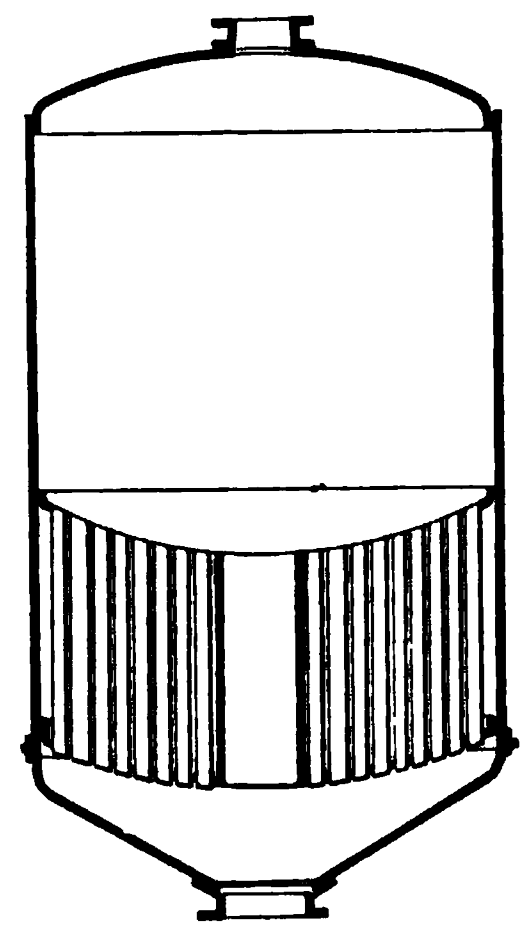

FIG. 121. — WERNICKE Vacuum Pan.

The vertical pan of the MARIOLLE-PINGUET type (Fig. 122) has the same heating surface as a horizontal pan. The upper portion is cylindrical, as in the compartments of a standard multiple effect. The heating tubes are contained in a cylindrical portion of the apparatus, and at each end penetrate a tubular plate and then a steam chamber, the one for the entrance of the vapor and the other for the exit of the condensed water. The steam circulation is consequently through horizontal pipes. The heating tubes are in two sections which may successively receive the vapors from the first and second compartments of a multiple effect. At the bottom are steam coils for live steam. In regard to the arrangement of the horizontal pans, there remains very little to add to what was said under the caption of Evaporation, with the exception, however, of the difference in the kind of vapor used, and, as pointed out in the several types of pans, the tubes and coils are so arranged that all will not be heated at the same time, but may be brought into use successively as the operation of graining progresses.

The horizontal vacuum pans, like the horizontal evaporators, have the characteristic feature of offering a very large heating surface, under which conditions the graining may be done with vapor at low pressure under very much better conditions than in the case of vertical pans. The mass being grained under these circumstances need have a level only slightly higher than the heating tubes, which, as previously pointed out, greatly facilitates evaporation. The tubes are in separate clusters, the lower series being first used. If two kinds of steam are employed for each series the

[1] Z., 53, 693, 1903

purging cocks connecting with the same necessarily differ. One objectionable feature of the horizontal pans is their emptying, but by the more modern modes of working the massecuite is very fluid and may be emptied by a pipe.

It is interesting to note that the vacuum pan with double bottom, formerly used, has now become obsolete, notwithstanding the fact

Fig. 122.—Mariolle-Pinguet Pan.

that it offered certain characteristic advantages, such as permitting the heating of the lower strata of the syrup, where steam bubbles are thrown out, thus producing a favorable influence upon the motion of the massecuite and its crystallization. From the standpoint of general heating, the double-bottom arrangement had very little value, for the reason that the coefficient of heat transmission was very small at that point.

The vacuum pan of the Wellner and Jelinek type (Fig. 123) consists of a compartment in the shape of a box, the bottom of which

slants at 45° and is closed by special balanced doors, which may be opened by simply turning a screw which works the lever holding the doors in position. The heating surface is divided into two sections, one receiving the live steam through *D*, and the other the exhaust steam of vapor from the multiple effect through $D_{\prime}$. The catch-all, shown in *F*, plays the same rôle as in an evaporating

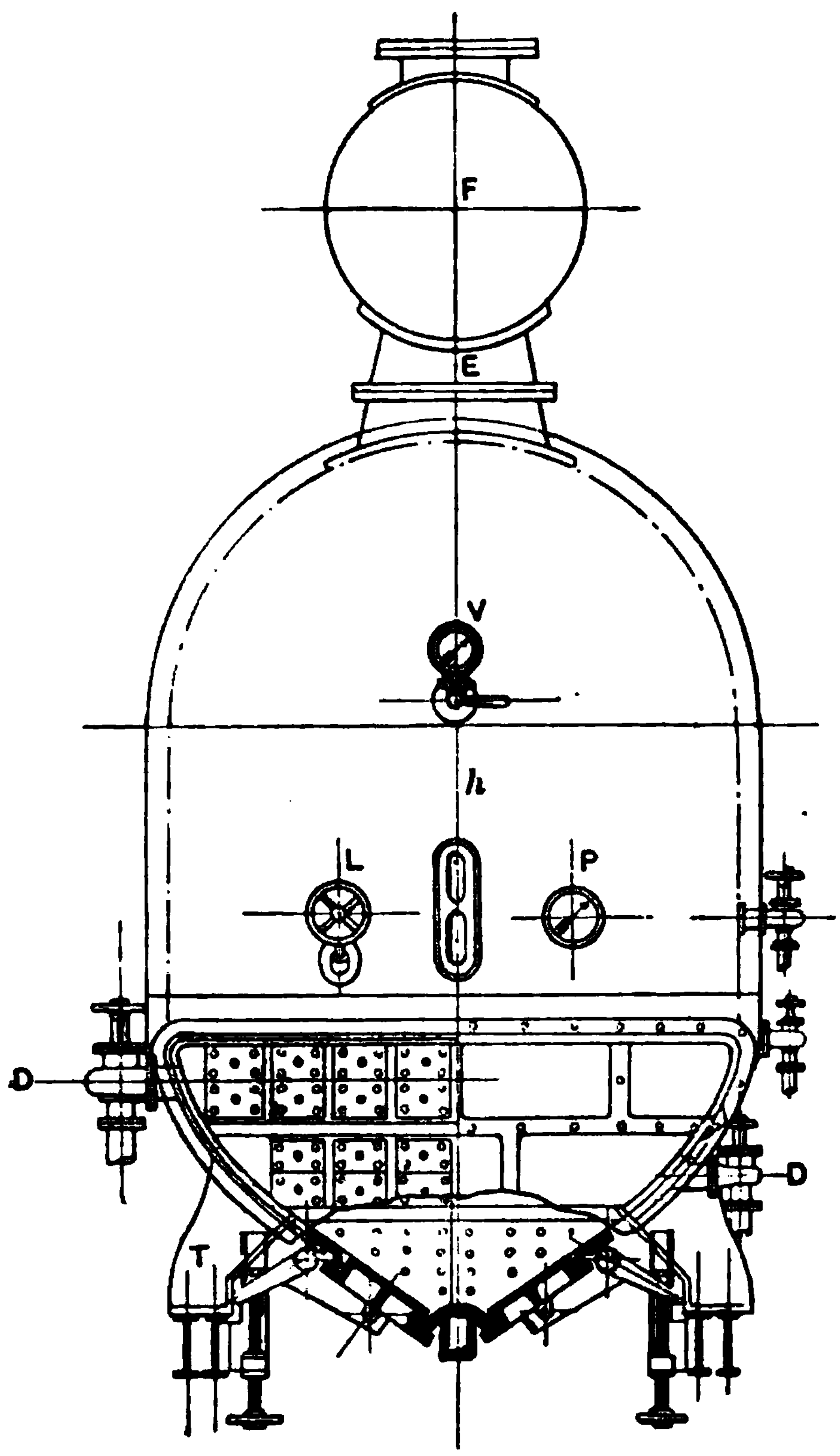

FIG. 123.—WELLNER and JELINEK Pan.

appliance. The heating surface consists of brass tubes 25 to 27 mm. in diameter, and sufficiently far apart to assure a satisfactory working of the apparatus. They are arranged one over the other at distances of 100 to 150 mm., the vertical spacing between them allowing the massecuite to escape when the pan is emptied. In this respect the combination differs from the alternate arrangement of the multiple effect.

In the LEXA-HEROLD vacuum pan (Fig. 124) the tubular cluster

is made up of brass tubes, 40 mm. in diameter, arranged in such manner as to allow free expansion. The lower tubes, which are used for starting the graining, are intended for live steam, while the upper tubes may be worked with two kinds of steam by dividing them into two groups. The entire bottom of this pan is made to move on friction rollers by an endless screw; by turning *A*, *B* is

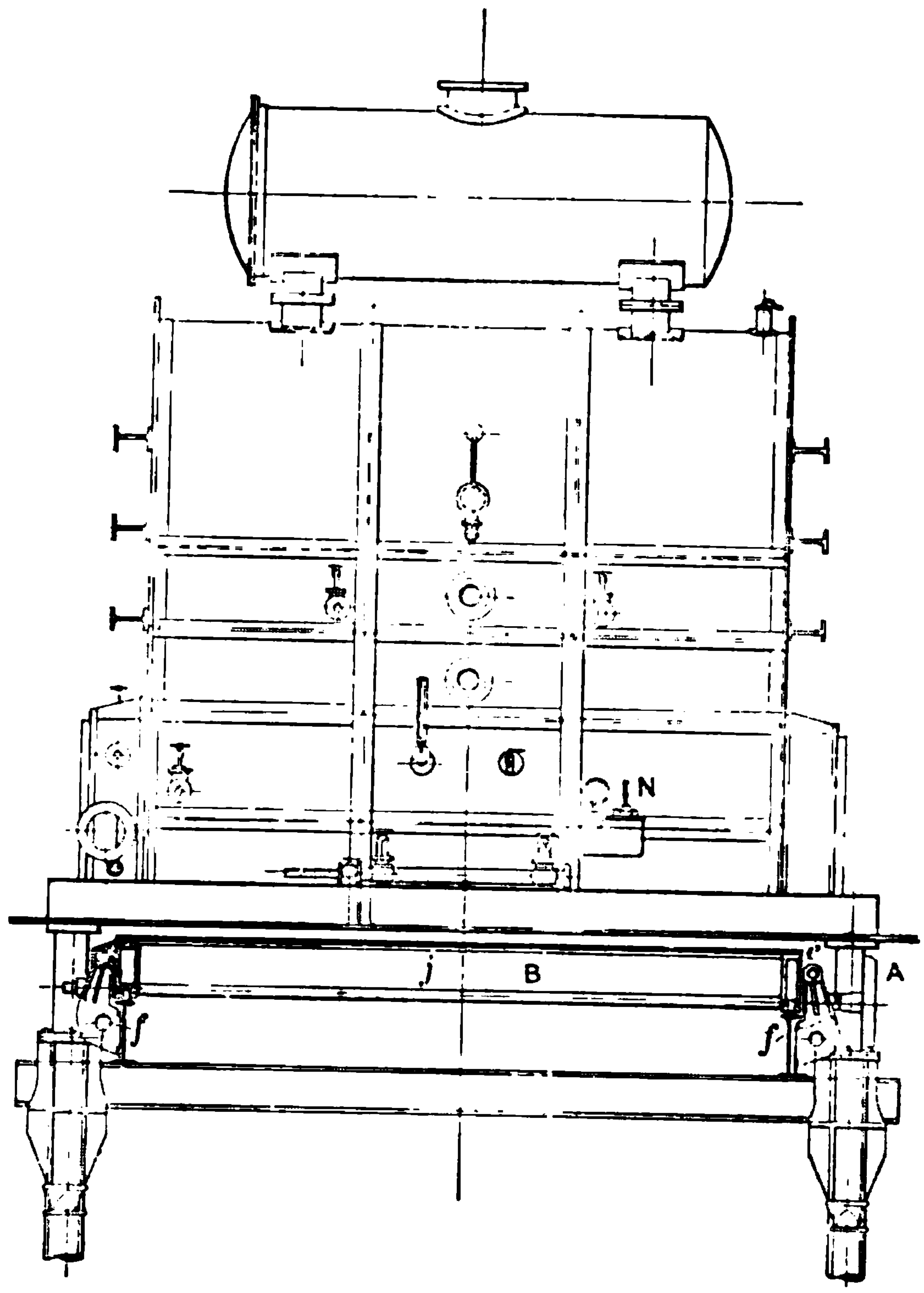

FIG. 124.—LEXA-HEROLD Pan.

forced to revolve. The pan is made tight by means of a rubber hydraulic joint filled with water from the pump, *N*.

In most of the appliances described in the foregoing special stress was placed upon the fact that facilities should be offered to heat the lower part independently of the upper. The reason for this, as will be subsequently explained, is to allow the graining to be begun with a much smaller volume of syrup than is necessary to cover all the heating tubes. If the upper portion was steam heated, burning and consequent sugar destruction would result,

and to overcome this and numerous other difficulties PRANGEY and GROBERT proposed a very original method. In their appliance the height of the massecuite remains the same, notwithstanding an increase of volume, which tends to do away with all the objectionable features mentioned in the foregoing. The idea is to permit the massecuite to extend horizontally when its volume increases, and at the same time to continue its heating. The arrangement, as

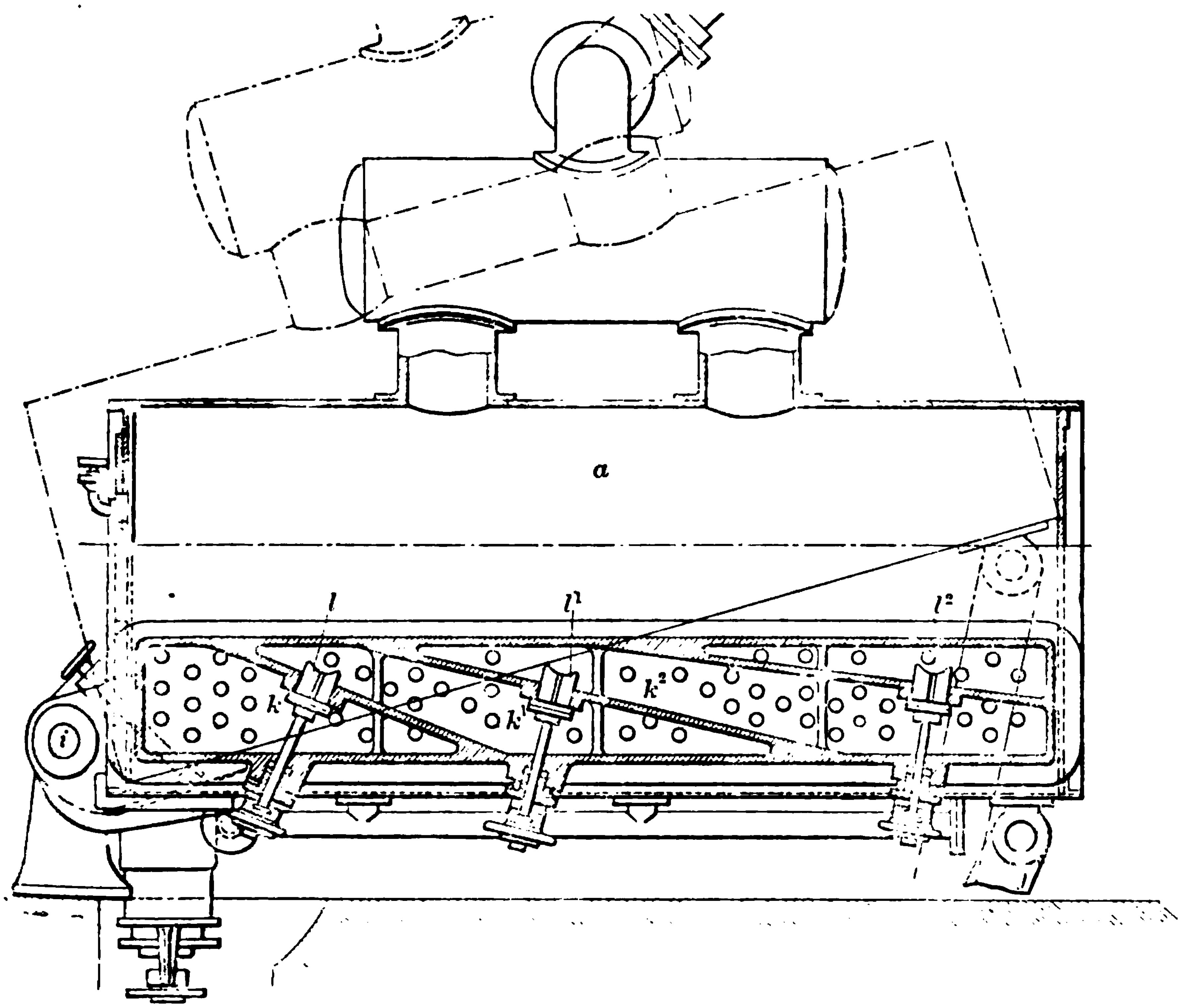

FIG. 125.—PRANGEY and GROBERT Vacuum Pan.

shown in Fig. 125, consists in slanting the apparatus, and in order to assure the varied inclinations necessary, by which the mass being grained is kept at the same level, the apparatus revolves around the axis, *i*, the movement being given either by the use of screw jacks, by a hydraulic piston working upon the lever, *j*, or by any other means leading to the same result. When the operation of graining commences, the apparatus, *a*, has a sharply inclined position, as shown by the dotted lines, this inclination being lessened

as the volume of massecuite increases and reaching the horizontal toward the end of the operation. Under these circumstances its height may be regulated in advance.

The heating system of an apparatus of this kind is divided into a number of independent sections, k, k^1, k^2, these divisions being arranged so as to correspond to a certain inclination of the apparatus, and being in active use only when the proper moment is

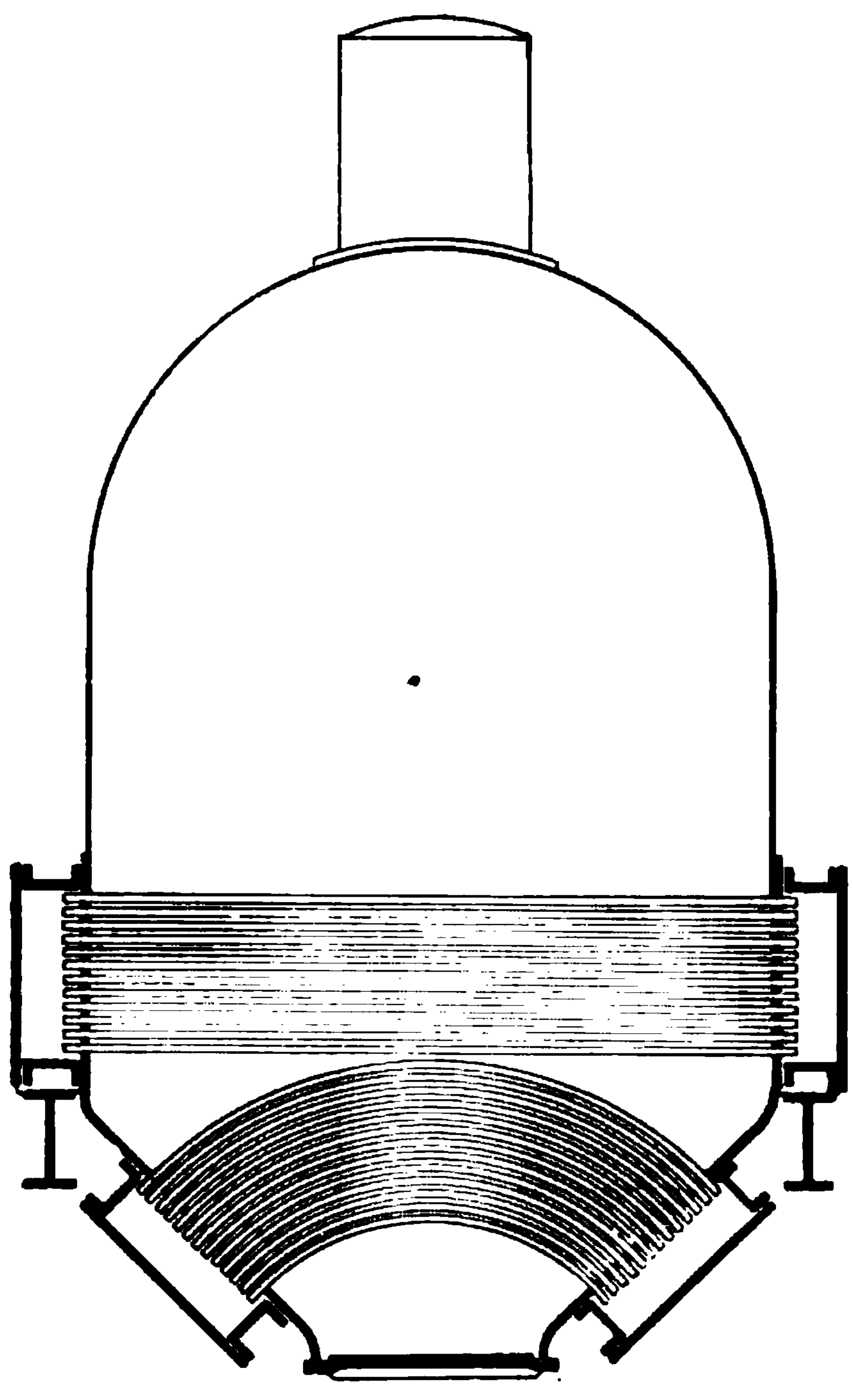

FIG. 126.—KASALOWSKI PAN.

reached. In the drawing are shown a series of openings in k, k^1, k^2, which are closed by l, l^1, l^2, and may communicate or not as the requirements may dictate. In such an apparatus the evacuation steam pipes leading to the condenser, as well as the piping for the steam used for heating and that for drawing off the massecuite, should be connected to the fixed pipes either by flexible pipes or by the use of a ball-and-socket joint. In another model of a constant-level apparatus there is a movable diaphragm which is displaced like a piston in a cylinder. As the mass increases in

volume the piston is moved back, and when it reaches the end of its stroke the vacuum pan is working at its maximum capacity.[1]

Another arrangement having the same idea in view is the KASALOWSKI pan (Fig. 126), in which the lower tubes are curved upward, offering considerable heating surface at their lower ends or at the bottom of pan which is conical. In the upper tubular cluster steam circulates only when the boiling of the mass is at its height. One of the characteristic features of this pan is that it is made up of a series of elements, all of the same kind, but placed side by side as in the GREINER pan, the advantage being that the working capacity of the apparatus may thus be indefinitely increased.

Size of the heating surface.—There is no standard to be depended upon for determining the size of the heating surface of a vacuum pan, and it cannot be calculated as for a multiple effect. The conditions for heat transmission vary considerably during graining, and the water to be evaporated from the syrup at different periods is extremely variable. Evidently this heating surface depends upon the kind of steam being used and the length of time the graining is to last. When heating with steam at a pressure of 0.7 atmosphere, except during the last period when the final water is being evaporated, and when the strike demands 10 hours, one-half square meter of heating surface per ton of beets sliced is considered sufficient. These proportions appear to be the ones adopted by most machine builders. Such data necessarily vary with the viscosity of different massecuites, which has an important influence upon the duration of the graining. The calculations based upon heat transmission are not reliable, for the reason that the conditions from first to last are constantly changing. The heat transmissions during graining are, according to POKORNY,[2] 24.65 at the beginning, 16.07 when half finished, and 6.17 when the strike is completed.

According to DESSIN,[3] one may accept for the copper coils of the vertical pan 25 to 35 sq. dm. of heating surface per hectoliter of working capacity. The vertical GREINER pans have 45 to 50 sq. dm. and the JELINEK 90 to 120 sq. dm. Exceptionally large heating surfaces are not objectionable when they occur at the bottom of the pan, provided that they do not in any way check the circulation of the mass being grained. The amount of heat to be brought in contact with the boiling syrup does not in this case de-

[1] S. B., Oct. 1903. [2] B. Z., 20, 7, 1895 [3] S. I., 41, 568, 1893.

pend upon the size of the heating surface, but upon the volume and pressure of the vapor or steam introduced into the heating chamber. Generally, with large heating surfaces only a portion can be brought into activity, and for this reason it seems rational to divide them up into several divisions, each having passages for the entrance of steam and the exit of water, and which may be heated with steam as the occasion may demand. Under these circumstances the evaporation may be regulated with the steam valve, so that the crystallization is accomplished under the most favorable conditions.

CLAASSEN says that it is difficult to state in advance which construction and which heating surface are the best. A first-class pan man can obtain very satisfactory results in almost any vacuum pan, provided the heating surfaces are sufficiently active and form no obstruction to the circulation. Because one pan man obtains poor results with a new apparatus, while an old vacuum pan handled by an expert shows excellent graining qualities, one cannot conclude that the new pan is inferior to the old one. Graining is an art learned in a very empirical manner, and must be relearned for each new model of pan and with each massecuite handled.

Kind of steam used.—As previously pointed out, different kinds of steam are used during graining. For the first concentration, the vapor from the multiple effect, or exhaust steam, answers the purpose; but as the operation advances a greater fall of temperature is needed, especially in very large pans, and as this necessitates hotter steam and higher pressure live steam must be used in the tubes. In the construction of a vacuum pan it is desirable to keep the heating surface as near the bottom as possible, thus allowing the operation of graining to begin with a very small nucleus.

The steam coils should be provided with purgers. It is most important that all the purgers be in perfect working order and provided with safety valves, otherwise, when working with live steam, there is constant danger of explosions. In case the heating is done with vapors at a pressure lower than the atmospheric pressure, the purging pipes are connected with the condenser, otherwise they have an air exit. Experience shows that the pan man frequently allows too much steam to escape through these openings, hence the desirability of placing a diaphragm between the joints.

Circulation during graining.—The thorough circulation of the syrup in pan during its further concentration and subsequent graining is even of greater importance than it was for the juice in the

multiple effect, as the viscosity of the massecuite is necessarily considerably greater than that of syrups, and every effort should be made to have the surfaces of the coils and heating tubes brought continuously in contact with new concentrated syrup. The viscosity is a retarding element, and if not overcome considerable sugar destruction will follow.

Numerous discussions have arisen as to whether the temperature of the massecuite was greater or less at its upper than at its lower surface. According to PINI,[1] the temperature at different parts of the massecuite may vary from 11° to 13° C. These observations can be made only under very exceptional conditions. But no matter what these differences may be they are considerably reduced when there is a satisfactory circulation upon the heating surface of the mass being boiled. ABRAHAM[2] points out that an active circulation is very favorable for the satisfactory utilization of the heating surfaces, but he argues that the shapes of the crystals are altered by the constant friction against each other and the sides of the pan. As there is a uniform temperature in the apparatus this fine grain does not dissolve, and with this idea in view he uses baffle plates to check the motion. It is claimed that by this means the quantity of fine grain is considerably lessened. Furthermore, there will be a series of layers throughout the mass which will all have different temperatures, the variation being more than 10° C., which condition this authority claims will tend to redissolve all the smaller grains of sugar, should any be formed. These arguments are interesting, for they show how great is the variance of opinion even among experts, but the suggestion in question has never, to the writer's knowledge, been practically accepted.

Numerous modes have been introduced which give a practical solution to the circulation of the syrup in vacuum pans. Among these are the suitable arrangement of the heating surfaces and the sheet-iron guides for the motion of the massecuite, some purely mechanical devices, and a long series of methods based upon the injection of gases, vapors, etc. The arrangements shown in the foregoing appliances of WERNICKE (Fig. 121), and especially in that of HAACKE, are very favorable to the motion of the massecuite in a vacuum pan. The gas bubbles liberated on the periphery of the tubular surface raise the hot liquid and then fall to the bottom of the apparatus by a large central tube in which they can no

[1] Z., 42, 351, 1892. [2] N. Z., 41, 50, 1898.

longer raise the mass, and a circular motion results. A similar motion is obtained in the FREITAG arrangement (Fig. 127), which apparatus differs very little from the one just mentioned, but to make sure that the motion shall extend throughout the entire mass, from the top to the bottom of the apparatus, there is placed in the central tube, *a*, another tube, *c*, which may be raised with the level of the massecuite, and so arranged that it is at a slightly lower level than the surface of the boiling mass, which rises in the tubes of the cluster and around the periphery, returning by the central tube, *c*.

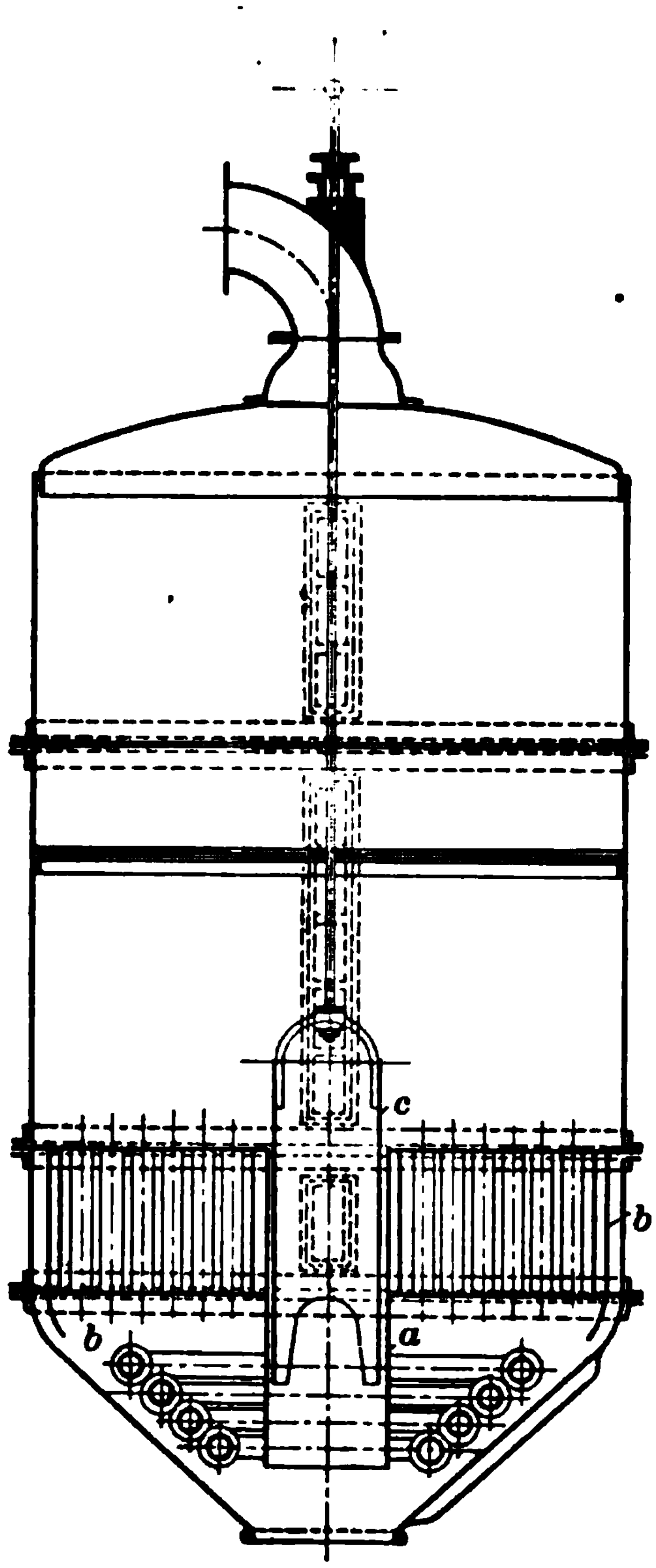

FIG. 127.—FREITAG Circulator.

Vacuum pans.[1]—It had been previously proposed to place between the steam coils of vertical pans, or between the horizontal tube clusters of the horizontal pans, small vertical sheet-iron boxes, open at their upper and lower extremities. The massecuite is heated on the tubes, becomes specifically lighter, and rises externally along the sheet-iron boxes, descending by the interior of the boxes, where the liquid is less hot and light, due to the fact that it has not been directly submitted to the action of heat. There follows an intense circulation favorable to the evaporation of the liquid and the development of crystals.

Vacuum pans as made by some builders[2] have two long circulating tube attachments. One of these is at the centre of the tubular cluster and the other around the exterior. The heated massecuite descends through the open spaces on each side. Furthermore, the circulating tubes are made of several pieces, placed one in the other, that may be lifted in such a way that the heating con-

[1] D. Z. I., 26, 633, 1901. [2] D. Z. I., 24, 1754, 1899.

tinues through all the tubes, whatever may be the level of the massecuite, which circulates from the top to the bottom of the apparatus.

Among the appliances in which there is a mechanical agitation in pan during graining is the REBOUX arrangement (Fig. 128), which consists primarily of a sheet-iron horizontal cylinder. The heating is effected through four systems of tubes, and at the centre of the apparatus an axis, bearing several arm agitators, revolves, bring-

FIG. 128.—REBOUX'S Vacuum Pan for Graining, in Motion. End View.

ing the massecuite continuously against the heating tubes. The central shaft revolves at the rate of four revolutions per minute, the gearing which gives the motion being outside of the pan. REBOUX has also applied the same principle to vertical pans. FREITAG, LENTZE, GROSSÉ, and others have constructed numerous appliances, all having the same idea in view. They are mainly used for after-products, which will be considered under another caption. Numerous other pieces of apparatus have been invented in which the agitators themselves are the heating surfaces. Among these may be mentioned the combinations of SZCZENIOWSKI and PIONTKOWSKI, HECKMANN, etc.

The CZAPIKOWSKI[1] pan is a horizontal cylinder, at the bottom of which rotates a tubular heating surface. The steam is supplied to it through a hollow shaft and then passes into a distributing chamber. The motion is given from the outside. At the other end of the axis is the same arrangement, except that the chamber is divided into two sections. The condensed water from each of them may have an easy exit through the end central shaft. This tubular cluster makes a revolution in two minutes, the massecuite is constantly renewed on the surface of the tubes, and there is no danger of caramelization. The heating surface may be very large and heated with steam at low pressure.

Very few of these mechanical arrangements have been practically used, but are of special interest on account of their marked departures from existing methods. In some cases the arrangement is too complicated, and in the others the conception has very little value, the inventors evidently not being familiar with certain requisites for graining.

PFEIFFER[2] has obtained satisfactory results by keeping the massecuite in motion during the graining in pan by steam injection at a reduced pressure. This steam is distributed through vertical pipes open at the bottom. The steam that rises in the interior of the pipes, in the form of large bubbles, raises the massecuite, forcing it out of the upper opening, while the new product enters at the bottom. A continuous circulation of the mass being grained is thus obtained. The steam used for this circulation is made in a special appliance of rather diminutive size. In it, however, the concentrated juice is cooked before it is introduced into the vacuum pan at a pressure about equal to that existing at the lower part of the vertical pipes. The upper openings of these pipes are at different levels, depending upon the level of the massecuite, and the pipes in question enter into function one after the other. These pipes may be placed outside as well as inside of the vacuum pan. The same action may be obtained with atmospheric air at a reduced pressure or an alternate action of steam and air.

Syrup distributors.—There is one instant during graining when it is desirable to obtain very rapid motion of the massecuite in the pan, that is, when new syrup is drawn into the mass. The latter being more fluid than the product that has undergone the first phases of graining, the mixing offers certain difficulties, and to

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[1] C., **11**, 244, 1902.

[2] Oe.-U. Z., **31**, 614, 1902.

overcome this difference of densities it is important that the syrup be introduced into the pan with considerable force. This is accomplished by the DELAVIERRE[1] apparatus, in which the syrups are injected under considerable pressure through small injectors fed by a powerful pump. With the same idea in view, GREINER proposed to decrease very considerably the section of the pipe feeding the syrup to pan.

It must be noted, however, that for the rapid filling of the pan with concentrated juice the diameter of the pipe must be reasonably

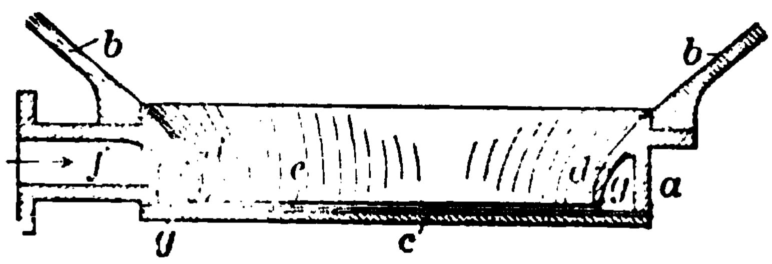

FIG. 129.—GREINER'S Inlet for Syrup.

large, but the subsequent flow should be simply a small jet entering the pan, so as to keep the newly formed crystals well supplied with fresh syrup. In most combinations the inertia of the new product coming in contact with the granulated mass prevents its penetrating to the interior and it rises to the surface. A pipe with a very small diameter would under such circumstances render excellent service; there should be several injectors placed at the bottom of the pan. In Fig. 129 is shown the GREINER manner of arranging at the bottom of the vacuum pan a circular gutter, *g*, which communicates with the feed-pipe, *f*, and also with the interior of the apparatus through the slit, *e*, which divides the syrup introduced. The outer border, *a*, of the gutter tightly closes the apparatus with the register *c*. In another GREINER[2] arrangement the suction pipe has at one end a widening closed by a disk which is worked by a lever receiving its power through a screw placed in the interior of the aspiration pipe.

Vapor-exit pipe.—The vapors produced in the pan escape through a catch-all. This may be closed by a large valve, by means of which the vacuum is regulated. The apparatus is thus put in communication with the condenser. A very simple method[3] to prevent condensed water from the exhaust pipes of the vacuum pan from coming in contact with the massecuite during graining

[1] La. S. B., **25**, 383, 1897.
[2] D. Z. I., **26**, 1709, 1901.
[3] D. Z. I., **24**, 1618, 1899.

consists in giving the said pipe a V shape, and placing at its lower part a cock which remains open during the entire period of the pan's working. This does away with the solution of sugar, caused by the accidental entrance of the hot water into the apparatus. It is unnecessary to have a special condenser for the vacuum pan, as the one connecting with the multiple effect answers the purpose.

Emptying valves.—The exit openings of a vacuum pan are in most cases closed by a cone. Where the strike remains comparatively fluid these openings are closed with a piston valve. In the GREINER vacuum pans this opening is closed by a plate moving on friction rollers, whose motion is governed by a screw. Numerous devices have been invented to accomplish this work from the floor on which the pan man stands.

Massecuite.[1]—It has been proposed to use dovetailed bottom gates. The end portion is bevelled and slides in a groove. The arrangement is such that the more one pushes the register forward the closer it is pressed, owing to the bevelling on the surface, which renders it perfectly tight.

In the horizontal vacuum pan emptying offers certain difficulties which do not exist in the vertical pan, especially when the massecuite is very consistent. In Fig. 123 is shown how this emptying is accomplished in the WELLNER and JELINEK apparatus. In the BREITFELD and DANEK pan the bottom also moves on friction rollers, and the entire plate is worked by a piston put into motion by hydraulic pressure. The rubber joint filled with water effects a satisfactory tightness. In the LEXA-HEROLD apparatus, as previously mentioned, there is very much the same arrangement. To facilitate[2] the emptying of the pan it has been proposed to force compressed air into the interior, after the strike is completed. This air will raise the massecuite and thoroughly mix it. To keep the observation lenses of the pan clean small steam jets are placed in front of them, the steam falling on the surface of the glass in the form of a spray. This cleaning may be done as often as the occasion demands.

Piping.—The principal pipings of a vacuum pan are those for filling with syrup, etc., and the steam pipes and coils used for heating. The suction valves for the concentrated juice or syrup and after-products should be sufficiently large and be placed in a convenient position. The pipes to which they are attached, connecting

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[1] Z., **53**, 106, 1903. [2] D. Z. I., **24**, 1044, 1899.

with the interior or exterior, should lead to the lower part of the pan, which should also have a pipe for the introduction of water or carbonatated juice to melt any false grain that might be formed. A small steam pipe for cleaning the pan is also a very essential adjunct.

For steam or vapor for heating, one should be able to utilize steam at either high or low pressure, according to circumstances, and the necessary communications should be easily made through large valves. Evidently the heating installation should terminate with a purging device for the water of condensation, and care should be taken that the ammoniacal gases escape readily. The heating chamber and the coils should also have a small connection that they may be filled with water, so as to stand the pressure test.

CLAASSEN advises to place at the bottom of the apparatus a coil with suitable perforations, or any other device that will permit the injecting of live steam into the mass, thus forcing it into motion. After the strike is completed, and the apparatus is emptied of its contents, these devices may be used for cleaning the pan.

Accessories.—The pan should be provided with every fitting that facilitates the watching of the process of graining. The testing cock or the proof sticks should be placed in a suitable position, that is to say, where there is sufficient motion of the massecuite, so that a sample taken represents an average of the contents of the pan. The proof sticks from this standpoint are more desirable than the testing cocks. On the other hand, it is possible to obtain a very satisfactory sample when the graining begins, and as the object at that time is to obtain the sample as rapidly as possible, the use of the testing cock is preferable. This consists of a specially devised faucet differing from the ordinary cocks, as it has no thoroughfare but a simple cavity that fills with massecuite when turned toward the interior of the apparatus. Beside the proof stick there should always be ample arrangements for observation after a sample has been obtained, such as a shelf where the slips of glass holding the sample may be placed.

The lower part of the apparatus should have a number of eye-glass or observation windows, lighted in such a manner as to permit one to see into the interior. The thermometer bulb should penetrate a certain distance into the apparatus, and the pan should also have a mercury gauge to indicate the condition of the vacuum. The pan man ought to be able to read on the gauge the pressure of the steam used for heating, also as it leaves the coil, or whatever device used.

Crystallization.—The crystallization of the sugar in the syrup has a tendency to commence when the water in which the sugar is dissolved is not sufficient for its solution. For each temperature there is a saturation point at which no more sugar can be dissolved, and this condition must be reached before the sugar commences to separate from the thick syrup. If the saturated solution is obtained at a comparatively high temperature a certain amount of sugar should begin to crystallize upon cooling, for the simple reason that water at a low temperature will not hold as much sugar in solution as when hot.

The fact is that crystallization commences slowly only when the quantity of sugar dissolved in a saturated solution is in great excess of what it should be, and ceases when the normal conditions of saturation are established. As long as the quantity of sugar dissolved remains higher than it should be at a given temperature the solution is said to be supersaturated. The tendency to crystallize is in direct ratio to the degree of supersaturation. In the case of pure syrups in supersaturated solutions but a very small quantity of sugar can exist in a supersaturated condition, while with impure solutions the quantity of sugar in a supersaturated condition can be sometimes considerable. This state of supersaturation continues for some time before the crystallization begins.

At lower temperatures the difference between a saturated and a supersaturated solution is greater than at higher temperatures, and after reaching a certain point the crystallization proceeds with considerable activity. By now obsolete modes of sugar manufacture it was customary to abandon the massecuite to a slow cooling, when all the sugar in supersaturated state would separate. This method continues to be used for after-products. There are other conditions which favor crystallization of a supersaturated solution, such as the introduction of sugar crystals to form a nucleus for the crystallization of the mass. The same results may be attained without the introduction of sugar into the mass being grained. When the degree of supersaturation is pushed far enough at a given moment very minute crystals of sugar will separate from the syrup, and these crystals will then act as a nucleus for the centres of crystallization. If this condition of supersaturation is continued for some time the sugar in the syrup will depose itself upon the crystals already existing, allowing them to increase in volume. Later on the elements known as viscosity, etc., play an important rôle, and obstruct the sugar crystallization.

From what has been said it becomes evident that the art of graining consists in offering every facility for the small crystals contained in the mass to grow, at the same time preventing a too high supersaturation which would tend toward the formation of new crystals alongside of those already existing. The latter condition would result in a massecuite consisting of crystals of various sizes. The value of the product is then necessarily considerably lessened and offers many difficulties during the swing-out operation.

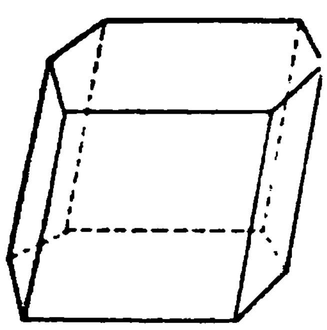
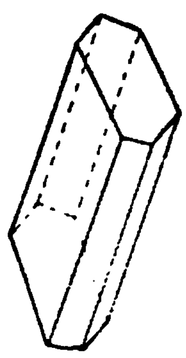
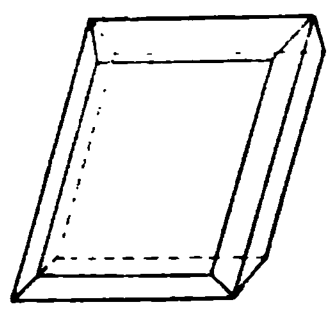
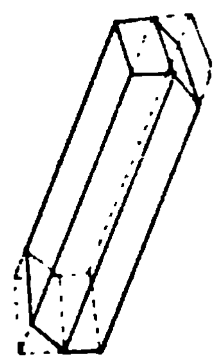

FIG. 130. FIG. 131. FIG. 132. FIG. 133.

Ordinary Shapes of Sugar Crystals.

Shape of crystals.—Saccharose crystallizes as an oblique prism with rectangular or rhomboid base, derived from the truncation of four homologous sides. Figs. 130, 131, 132, and 133 give an idea of their general aspect. In some cases they present the appearance of cakes (Fig. 134), and then again that which characterizes cane crystals, these being frequently stuck together in

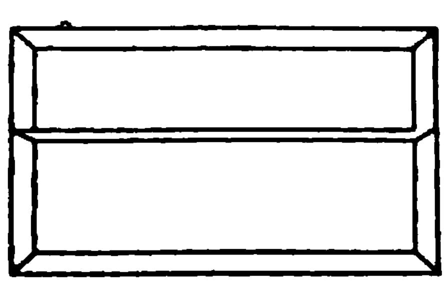
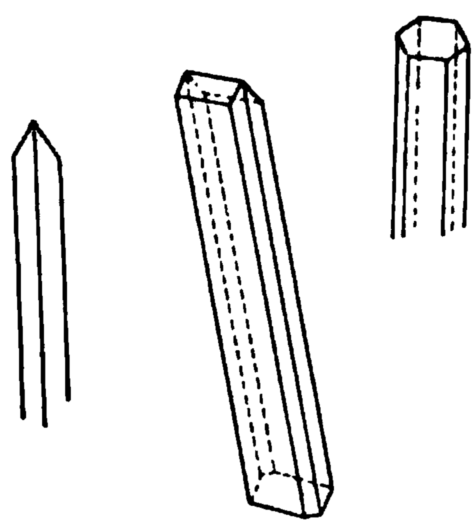
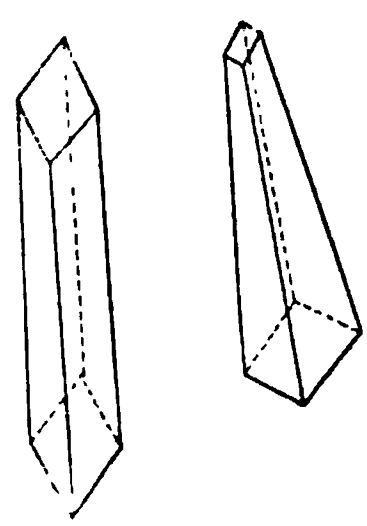

FIG. 134. FIG. 135. FIG. 136.

Abnormal Shapes of Sugar Crystals.

pairs. POISSON claims that this is one of the characteristic indications of the presence of glucose. The crystals are also frequently much elongated, as in Fig. 135, and also needle-shaped, as in Fig. 136.

There are numerous problems relating to crystallization remaining to be solved. Whatever the laws governing the process may

be, they hold good for all substances. The experiments of VOGELSANG show that, during crystallization, globules, more or less round, are formed. According to recent theories, comparing them with the cells of plants, etc., these globules multiply by partogeniture, then form clusters of 2, 3, and greater numbers in the direction of the optical axis of the crystal and finally crystallize.

Factors that influence crystallization.—The factors influencing crystallization are the viscosity, size of the crystals' surface upon which the new sugar crystallizes, and the so-called coefficient of supersaturation, which is very important. DEGENER[1] maintained that the crystal in the state of formation impoverishes the solution in which it is placed, and osmotic currents are formed which carry the molecules of supersaturated sugar from neighboring strata in the direction of the growing crystals. The viscosity of the liquid paralyzes these currents, and it is easy to understand that the mechanical motion of the mass, bringing the various molecules in state of supersaturation in contact with the crystals already formed, compensates for the viscosity to a certain extent, and necessarily assists in producing the requisite conditions for the rapid growth of the crystal.

Besides this osmotic current, there is the molecular attraction of the crystal in the state of formation. This attraction is proportional to the mass. The crystallization depends also upon the area of the crystals already formed. CLAASSEN'S[2] calculations show that the sides of large crystals contained in one kilogram of sugar represent an area of about 3 sq. m.; on the other hand, in the case of small crystals this area is about 5.5 sq. m. Upon these areas is deposited the supersaturated sugar contained in the mother liquor, from which it is concluded that a great number of small crystals offers especial advantage for crystallization, a fact long since demonstrated in practice.

Claassen's theory of supersaturation.—The whole issue of sugar transformations during graining is most interestingly explained as follows:

If we suppose S to be the quantity of sugar dissolved, for one part water, at a given temperature, in a saturated solution, and S' the quantity dissolved, for one part water, at the same temperature, in a supersaturated solution, the formula $C=\frac{S'}{S}$ represents the

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[1] S. I., 28, 656, 1886. [2] Z., 44, 394, 1894.

coefficient of supersaturation, that is to say, how many times more sugar is dissolved at a given temperature in a supersaturated solution compared with a saturated one. This coefficient is of fundamental importance in the crystallization of sugar. While all other conditions, such as viscosity, etc., vary with the temperature, the coefficient of supersaturation is completely independent of heat. If the graining or any other process of crystallization take place at a high or low temperature, the most desirable coefficient of supersaturation for the formation of new crystals and their increase in size are always the same, within the practical limits of temperature, for the after-products and the concentrated juices or syrups of the same purity, while, as already explained in the foregoing they vary with a variation in purity. Furthermore, the coefficient of supersaturation should be larger for the formation of grain, and smaller when the solution already contains crystals to help in the crystallization.

For a well-regulated operation, the supersaturation, and consequently the temperature, should be the same at all parts of the mass. The supersaturation undergoes certain changes during graining in pan, partly due to the evaporation on the heating surface, and consequently in that portion an excessively supersaturated solution is formed which could bring about the formation of new small crystals. Then, on the other hand, at the spot where the concentrated juice enters the pan, the supersaturation is entirely destroyed, and the crystals completely formed may pass again into solution if the concentrated juice is not immediately distributed throughout the entire mass and mixed with the supersaturated syrup surrounding the crystals. For this reason a proper circulation of the mass in the vacuum pan should be secured.

Agitation by means of propellers and spirals give excellent results when molasses are being worked in pan; but they do not give equal satisfaction with concentrated beet juices, because the space in most vacuum pans is very much too small for these devices. A motion produced by the free introduction of steam has proved very advantageous. The steam bubbles rise from the distributors placed at the bottom and mix the mass, the claimed advantage being that the heating surfaces are grazed, and there need be no fear of local supersaturation. This condition is never realized with spiral or other agitators. The bubbles formed by steam injection also prevent in a considerable measure the formation of false grain. The concentrated juice should never be colder than

the boiling temperature of the vacuum pan when it is introduced, for the reason that not only would the mixing otherwise be more difficult, but also there would be a cooling of the massecuite, which would result in the formation of small crystals.

For the formation of grains in the pan the concentrated syrup should be supersaturated, and the formation of crystals should be accelerated by a sudden motion of the mass, accomplished by a brusque and rapid opening of the valve through which the syrup enters the pan. The greater the supersaturation, the stronger the motion, and the greater will be the number of crystals formed Other things being equal, the quantity of crystals produced de. pends upon the degree of concentration and the amount of juice entering the pan. However, one may maintain the supersaturation at different degrees for the production of crystals of a given size, because, by frequently opening the entrance valve and admitting the concentrated juice, one may obtain a considerable number of crystals even in slightly supersaturated juice, and inversely it is possible to produce very few crystals in a high-supersaturated syrup by introducing only small quantities of concentrated juice into the pan.

The smallest practical coefficient of supersaturation for the formation of grains in concentrated juice of 90 to 92 purity may be said to be 1.2. With a smaller supersaturation the operation would last for a long time before sufficient crystals would be formed, and there would then be a possibility of the crystals becoming partially redissolved when fresh concentrated juice is drawn into the pan. The highest coefficient of supersaturation should be about 1.5 to 1.6.

Whatever be the method of graining in the vacuum pan, efforts should be made to prevent new crystal formation after a nucleus has been formed. As long as the crystals are small and offer comparatively limited surfaces for the deposit of sugar, the syrup that surrounds them, the mother liquor, should be kept in only a moderate condition of supersaturation. The reason for this is that the mother liquor continues to have nearly the same purity as the syrup from which it is obtained, and possesses the property (because of the motion produced by the suction of fresh concentrated juice into the pan) of producing crystals with a coefficient of supersaturation of 1.2. During this period of the graining, the supersaturation cannot become greater than that which corresponds to this coefficient, and it is safer not to attain this maximum.

The strike can be continued in two ways,—by continuous suction of the syrup into the apparatus, or by intermittent suction. By the first method the suction valve is regulated in such a way as to permit drawing into the pan the exact volume of concentrated juice necessary to maintain the mother liquor at a constant supersaturation equal to 1.1, which is recommended as an average. In no case is it desirable to exceed that limit at the start. By the intermittent suction method, the syrup is drawn into the pan when the coefficient of supersaturation has risen to about 1.2, and the suction continues until the supersaturation is nearly destroyed, that is to say, until the coefficient falls to 1.0. The mother liquor cannot be diluted below the limit of supersaturation, for the reason that the crystals would redissolve. A general rule for conducting these two modes of graining is, that, when the operation is to be conducted slowly, the coefficient of supersaturation, mainly the extreme limit, should be lower than when it is to be rapidly conducted.

It is only when the crystal formation has been excessive, or when new small crystals are formed, owing to neglect in conducting the graining, that one may draw in by suction a volume of concentrated juice, so as to put the mother liquor in a condition of undersaturation and dissolve the excess of crystals. This dilution is frequently accomplished, not with concentrated juices that already have a high density, but by the suction of hot water into the pan. This may be sometimes a necessity towards the end of the graining, as it permits the completion of the strike without the formation of small grains.

As the size of the crystals increases, the purity of the mother liquor decreases during the process of graining, and for this reason it is most advantageous to keep the coefficient of supersaturation of the mother liquor at 1.2 during the development of crystals and to allow it gradually to rise, reaching 1.3 as the last concentrated juice is drawn into pan.

The art of graining consists in determining the exact supersaturation from exterior signs, such as the string test, the fluidity of the samples of massecuite, in making allowances for the temperature, and the transparency of the syrup surrounding the crystals, and in maintaining this supersaturation in the mass. The entrance of the steam into the coils should be regulated so as not to result in excessive evaporation in order to leave, after each suction of juice, ample time for the sugar to deposit upon the existing crystals.

and to make the purity of the mother liquor fall continuously. The duration of the graining can be reduced only at the sacrifice of the yields, unless, during the final working of the massecuite in the crystallizators or in the malaxors, the previous neglects are compensated for. As a general rule, the operation of graining should last as long as possible, and in no case should the strike take less than six hours. An apparatus permitting this operation to be accomplished in less time is not necessarily the best, as the favorable action of time cannot be compensated for by any construction.

The size or the capacity of the vacuum pan has no influence upon the quality of graining. The crystallization can be just as satisfactory in a small apparatus as in a large one, provided they both have been properly made. The essential condition is not to commence the grain formation with too large a volume of syrup—in no case more than one-fourth to one-third of the pan's capacity—so that the crystals may have time to increase in size during the period that follows.

Practical hints respecting graining in pan.—According to Dureau,[1] the art of graining in pan is of French origin, but a discussion of the correctness of that assertion would take us beyond the scope of the present writing. Baumann,[2] as early as 1849, resorted to a method very like graining. Walkhoff,[3] in 1853, gave the first description leading to some practical rules for properly handling the pan. It was only in 1870 that the process became general in Germany.

The practical methods now followed by pan men in handling the mass in a vacuum pan differ to such an extent that no cast-iron rules can be given. However, in what follows, the points mentioned are intended only for the general guidance of those who have the work to do, and the treatment must evidently vary with the different circumstances that present themselves.

The first essential is evidently to make sure that the bottom valve or opening of the pan is closed, and then that the vacuum valve is gradually opened; otherwise the air pump could not keep up the required vacuo, and this would necessarily cause much trouble, such as the remelting of the sugar already grained in another pan if not yet sufficiently developed. When the vacuum reaches 0.6 atmosphere, it is recommended to keep the vacuum valve so that the same conditions may continue until the strike

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[1] Z., 17, 298, 1867. [2] Z., 17, 559, 1867. [3] Z., 4, 67, 1854.

is completed. Syrup is then drawn into the pan, the quantity introduced varying with the mode of working. Its volume is either measured in advance or is known by the level it occupies in the apparatus. This constitutes the graining nucleus, and should be as small as possible, so that the crystals obtained may grow.

It is to be noted that the volume of syrup introduced should be at least sufficient to cover the coils or tubes used for heating. The air purgers of the heating chamber should be opened, and the steam, which is generally the vapor from the multiple effect or the fore-evaporator, gradually introduced. The steam valve is opened in full after a reasonable interval, and the water from the syrup is evaporated more and more, resulting in a thick, supersaturated mass. If this condition is allowed to continue, the sugar crystals rapidly appear; but, as they are not formed all at the same moment, they would be very irregular in size, and the whole condition of the massecuite finally obtained would be irregular and unsatisfactory. Consequently, every effort should be made to obtain an instantaneous crystallization in the nucleus, whereby all the crystals have the same starting point for their subsequent growth. The pan man then gradually introduces more syrup until a condition of viscosity, represented by a supersaturation determined in advance, is obtained. The vacuum before mentioned is maintained with a temperature of about 82° C.

Generally, the pan man commences his graining when a sample submitted to the string proof gives satisfaction. This test is made by sticking the forefinger into the thick sample of syrup, then pressing it against the thumb and rapidly separating, when there will be formed a syrup thread, or so-called string. If the conditions are satisfactory, a considerable volume of syrup is then introduced at once into pan, when there will follow a rapid granulation, an exact explanation of which phenomenon has never been given, though spontaneous cooling, etc., has been suggested. From this time on, great activity should be shown on the part of the pan man; not an instant is to be lost. Samples must be rapidly taken every few moments and examined by a lamp through strips of glass. The grain nucleus first manifests itself by the small shadow cast, or by the brilliancy of certain centres, and the growing of these crystals must be very carefully watched. The mass in the pan is then diluted so as to lower the supersaturation, until a degree is reached at which no more new crystals will form. When that condition is reached, the mass has a sufficient number of crystals

for the object in view. During a period of 8 to 10 minutes the crystals are allowed to grow, notwithstanding the existing limited supersaturation, and after this interval it is possible to decide whether the resulting grain is too small or too large. Generally, there is an excess, and a portion of the crystals must then be redissolved, which is effected by drawing more syrup into the pan. In all these manipulations the pan man, as previously pointed out, must show considerable judgment, as there are certain thumb rules which vary in each case and with the person conducting the operation.

During the period when the crystals are being dissolved the vacuum is frequently allowed to fall to 0.5 of an atmosphere, necessarily causing a certain rise in temperature, which may be still further increased by the introduction of additional steam in the coils. Under these conditions the solution is more rapid, but it should not exceed a certain limit, and when the limit is attained the vacuum of 0.6 of an atmosphere should be again established and the quantity of steam used lessened. A certain cooling of the mass in the pan results and the saturation point is again reached. The feeding of the grain may then commence, provided, however, that the nucleus is in a standard condition; otherwise it is important to recommence graining, as just described, or to dilute again the syrup, to lower the pressure and introduce more steam to dissolve the crystals in excess, as the case may be. Sometimes, when the number of sugar crystals is too small, the pan men resort to a second formation of crystals alongside of the crystals already formed. This way of working is not to be recommended, however, as the final crystals will be very irregular, and hence it is again emphasized that the exact point must be reached at first. Any method of graining may lead in a measure to what one has in view, but the uniformity of the crystal mass forming the nucleus is the important consideration. When this is obtained, a regular feeding and supersaturation of the solution will ensure the graining.

The syrup drawn into the pan from that time on may be continuous or intermitting. In the first case, the suction valve is partly opened, the position being made to vary with the resulting effect upon the mass being grained. If it becomes too fluid, the valve is closed a little more; if not sufficiently fluid, the valve is opened wider, etc. By the intermitting method a new charge is made only when the mass in pan presents a thick appearance. Experience seems to show that preference should be given to the

first method. As previously pointed out, the degree of supersaturation can be deducted from the viscosity of the syrup being grained. The projection against the peep glasses of the pan, or the feel of the sample, give a good idea of the viscosity. Some pan men can ascertain the degree of viscosity by the sound made by the vapor on its way to the condenser in passing through the valve.

Evidently the degree of supersaturation depends upon the purity of the syrup, and is also a factor in the rapidity with which the work has to be conducted. The greater the impurity and desire to grain rapidly, the higher must be the supersaturation to meet that end. If too low, as previously pointed out, the crystals grow very slowly. But supersaturation may be held abnormally high, and there will then be a moment when the sugar will separate suddenly, and this powder or *false grain* can never reach the size of the first crystals. The only way to prevent this formation is to keep the supersaturation at the standard degree. When the false grain is formed it should be remelted as described in the foregoing, but this is always followed by very irregular final crystalization.

When the operation has been properly conducted, the final mother liquor is very impure and contains little sugar and all the non-sugar. This condition is reached as the graining operation progresses. It is evident that, if an abnormal quantity of syrup is introduced into pan with the view of melting the false grain, the purity of the mother liquor will rise, which necessarily means a loss of time in its desugarizing. When this false grain forms, the mass is very thick, and the drops thrown against the observation windows form bubbles; if this condition continues they present a cloudy appearance. No better indication can be given of the pan man's ability than the regularity of the crystals in the final sugar. HERZFELD[1] has pointed out that most of the raw-beet sugars now made consist of excessively irregular crystals.

Upon general principles it may be admitted that the operation of graining demands time, when it is intended that the crystals shall attain a reasonable size. The length of time required depends upon the size and number of pans in the factory. As the operation progresses, the mother liquor becomes more impure and the crystallization in that medium is necessarily more difficult. On the other hand, when possible, it is desirable to hasten the crystallization, provided this may be accomplished without decreasing the quality

[1] Z., 48, 630, 1898.

of the final sugar; this may be effected by a high supersaturation, keeping within the limit of possible false grain formation. Ragot recommends that the coefficient of supersaturation be kept very low. According to Schnell,[1] the desugarization of the mother liquor is rapidly accomplished at the beginning of the graining operation; but from a certain point, say 70 purity onward, the crystallization is a very slow operation. The purity will fall 0.6 only after six hours.

Experience seems to show that a pan man can more readily handle a diluted syrup and obtain regular crystals than he can crystallize a comparatively dense syrup at 30° Bé., as it is customary to introduce it into pan. For this numerous explanations may be given. As there is more water to be evaporated, the mass is necessarily submitted to a more active motion, which under all circumstances is very favorable for crystallization. The attempt to handle very diluted syrups, at 20° Bé. for example, demands more steam and consequently more fuel, and is not economical even if the final results are more satisfactory. In other words, the increased value of the sugar owing to its regular granulation does not represent an additional money equivalent for the fuel expenditure.

It must be pointed out that the pan man is not always directly responsible for the false grain. It may be the outcome of a sudden fall of pressure in the steam taken from the multiple effect; or it may be due to the fact that the syrup supply stops at once without the pan man's realizing the fact; hence the importance of affording every facility for correcting mistakes before it is too late. In some beet-sugar factories it is customary to have in connection with the pan a pipe that allows the introduction of water into the mass, but a better plan is to have a pipe connecting with the waiting tank of the multiple effect and to introduce carbonated juice.

As the volume of massecuite increases, the crystals become more and more voluminous, as compared with the mother liquor. When the vacuum pan is nearly full, there follows what may be termed the tightening, or that condition in which the water percentage of the mass is lessened so that the massecuite may be satisfactorily handled in the operations that follow. This tightening operation is not always conducted in the same manner, as sometimes the crys-

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[1] C., 11, 627, 1903.

tallization is continued in special crystallizators. The tightening in this case should be pushed only to a moderate degree, and the mass kept sufficiently fluid to flow readily into the receptacle under consideration. This fluidity is very essential in cases where the mass is to be rapidly cooled in the appliances.

On the other hand, in the case of the SCHUEZENBACH boxes, if the massecuite is not tight, the sugar yields will be disappointing. When the tightening commences, and even towards the end of the graining, the low-pressure vapor originally used cannot furnish a sufficient fall of temperature for the work to be done, and one must resort to the use of live steam. Until the pressure exerted by the column of massecuite upon the coils can be overcome, little by little the pressure in the heating chamber will rise, reaching two and one-half atmospheres when the strike is finished. The pan man should arrange so as to reach that pressure gradually. The purger may be so adjusted as to whistle when the desired condition is reached.

When the graining has been properly completed, the handling of the massecuite must then be conducted under scientific principles. The purity of the mother liquor is then about 75, depending, however, upon many conditions, and in some factories it is even lower. If sufficient time were allowed for the graining all the sugar could be crystallized in the pan, but the length of time necessary renders such an idea impracticable. The operation is sometimes continued in another special pan. It appears doubtful whether a crystallization pushed that far in pan has advantages, and whether the ultimate working of the massecuite is not more satisfactorily accomplished in special crystallizors.

In order to show the different degrees of tightening, as accomplished by various methods of conducting the graining, it may be said that the limits of water percentage are between 4 and 10 per cent. If the massecuite is to be emptied into large tanks or small boxes about 5 per cent of moisture may be considered a standard. For the customary working of the massecuite mixers the product from the vacuum pan should contain very little moisture.

An appreciable increase in yield of sugar is only possible by the new methods of working the massecuite in the crystallizors, carefully regulating the cooling and the concentration of the mother liquor. With this idea in view, efforts should be made during the tightening of the massecuite in the vacuum pan to prevent the formation of new crystals alongside of the large ones already exist-

ing. For this reason the coefficient of supersaturation of the mother liquor should not exceed 1.3, even during the tightening.

When the pan man considers that the graining operation in pan is about finished, the steam entrance valve is closed and all communication with the condenser is shut off. Then the air is allowed to enter, the bottom closing door is opened gradually, and the massecuite is run into the crystallizators or the SCHUEZENBACH boxes. In some factories the crystallizators are placed at a higher elevation than the vacuum pan. In such case the communications with the condenser are closed, and either steam or compressed air is introduced into the pan. The massecuite under these circumstances is forced up into the tank through a pipe that passes from the bottom of the pan. In case the massecuite is made from pure beet syrup, it does not readily leave the apparatus, as it has a grainy. dry consistency, and is not fluid. On the other hand, when the pan man has introduced molasses into the strike, the massecuite is very fluid. Precaution should then be taken to open the bottom valves slowly to avoid the projections of hot massecuite.

Steaming out.—After the massecuite has been emptied from pan there always remains a certain quantity of the product upon the projecting portions of the apparatus and the heating surfaces, and these crystals will be only partly or incompletely dissolved by the syrup drawn into the pan when started again, which is already in a very concentrated condition. A few rather large grains will always exist during graining alongside of the new crystals formed, and this is in most cases not a desirable condition. By steaming out the pan the massecuite that remains is so diluted that it either runs off or even is dissolved.

It is especially advantageous to place a special perforated steam pipe before the observation windows, to the inside surface of which, as they project slightly, some of the massecuite necessarily adheres, which in most cases cannot, or at least not without difficulty, be removed, either by ordinary steaming out, by contact with the fresh syrup drawn into the pan, or by washing.

POCHWALSKY[1] advised the use of a perforated pipe running the entire height of the apparatus and placed at a distance of 30 cm. from the glasses.

When the perforations of these steam pipes are sufficiently small, there need be no apprehension of breaking the observation glasses by sudden contact with the steam.

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[1] La S. B., 21, 487, 1893.

The diluted massecuite, which toward the end of the cleaning becomes simply a weak juice, is run from the vacuum pan into a separate box, in case of working with the SCHUEZENBACH boxes, or when working with crystallizators it is simply run in the same and is used to dilute the massecuite which, as a rule, is too tight. It does not appear desirable to collect separately this thin juice, as the coefficient of supersaturation of the diluted mother liquor remains sufficiently high for its satisfactory working.

Appliance facilitating graining.—As previously explained, the progress of the graining may be readily followed from exterior indications, such as temperature, vacuum, appearance of the mass in the interior of the apparatus, etc. Without doubt, the most reliable indication is the direct appearance of the mass, as shown by the examination of a sample through a sheet of glass, either by daylight, or, better still, by artificial light from a petroleum lamp. It is to be noted, however, that there are many objections to this procedure. During the time that the sample is being examined important changes may take place in the pan, and, furthermore, the sample exposed to the air cools, and even after a few seconds its entire aspect can be altered.

The RASSMUS apparatus permits the examination of the crystals in the interior of the pan during the operation of graining. The illustrations herewith show the inside (Fig. 137) and the outside (Fig. 138) modes of lighting the observation windows. At the side of the window is an opening, *b*, through which passes a perforated rod, *c*, penetrating the mass being grained. The enlarged extremity of this rod, *f*, is closed by a disk of heavy glass, *e*, which presses against the observation window, *a*. In the swollen portion, *f*, and in front of a reflector, *g*, there is placed an incandescent lamp, *h*, which receives its current through the wires, *i*, in the tube, *c*. When drawn forward by the handle, *k*, the portion, *e*, rubs against the window, *a*, as much as the ring, *l*, holding *e*, will allow. In front of the observation window is a magnifying apparatus, *m*. When the lamp is lighted, the microscopic examination of the product left between the two glasses, *e* and *a*, may be made from the exterior. By pushing back the handle, *k*, and bringing it again into position, a new sample is obtained. In Fig. 138 the lamp, *h*, is placed on the outside.

Other appliances have been proposed, which are based upon an entirely different principle. MALLEZ watches the viscosity of the mass during the entire graining, and is thus enabled to reach a con-

clusion as to the concentration and supersaturation. The device[1] used consists simply of a vertical mixer with suitable arms, the motion being given from the top by a electrical motor. Upon the wire conducting the current is placed an ampere-recording apparatus. If the consistency of the massecuite increases, the resistance offered by the revolving mixer will also increase, and this will be shown on the ampere recorder, the voltage remaining constant. The pan man keeps the ampere indicator constantly before him, and

RASSMUS Observation Apparatus.

FIG. 137.—Interior Mode of Lighting.

FIG. 138.—Exterior Mode of Lighting.

the syrups may be introduced into pan when the mass has exactly the consistency determined in advance, for then the ampere resistance of the agitators will have become standard. It becomes also possible in the same way to regulate the water percentage of the massecuite at the time the strike is completed. The great simplicity of this apparatus is a recommendable feature.

CURIN has constructed an apparatus known as a brasmoscope, which permits one to follow continuously the progress of the concentration during graining. The device is based upon the boiling points of sugar solutions having different densities and under

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[1] S. I., 60, 606, 1902.

different vacuos. The idea of the brasmoscope was evidently suggested by the KLINGHAMMER[1] hepsometer. By this apparatus it may be determined when the tightening shall cease. The strike is considered completed when the temperature and vacuum indications show a specified difference. The CURIN brasmoscope (Fig. 139) consists of a thermometer, T, that has no direct communication with the other parts of the device, and is held in an open space of the wooden plank; care must be taken to have certain markings on the board to correspond with the thermometric scale. The vacuum indicator has two tubes; the shorter, B_2, is open and communicates with the receptacle, N, by the tube, B_1. The principal rôle of N is to retain the juice and condensed water, etc., carried forward by entrainment; these may be drawn off through the cock, R. The vacuum pipe's indicators may be lowered or raised by the screw, S. The graduated scale, V, is fixed. The third part of the brasmoscope is the saccharimetric scale, D, which may be regulated with the screw, K.

FIG. 139.
CURIN Brasmoscope.

The apparatus is made ready by pouring mercury, drop by drop, into the short tube of the barometric tube, B_2, until the level corresponds to O of the (V) scale. This is somewhat difficult to accomplish, hence the importance of the final regulating screw, S. The difference in the level of mercury in the tubes, B_1 and B_2, when the appliance is working, gives the intensity of vacuum as compared with atmospheric pressure; if this is found to be 580 mm., then the vacuum in pan is 58 cm. This difference is shown on the scale, V. The density is determined as follows: When the vacuo in the pan is 62 cm. and the temperature 75° C., the scale, D, is lowered so that the upper border of the pointer, A, is on the level of the mercury, at which time the scale of D, corresponding to the temperature 75 of the thermometer, will indicate 87°. Consequently, the liquid being boiled in the pan has a density of 87° Brix.[2]

[1] N. Z., 4, 24, 1880. [2] S. B., July 1898.

When the vacuum remains constant the formation of the grain is effected at a normal density, H. The effort should be made to keep, as nearly as possible, closely within the limits of this density, for it is an admitted fact that sugar granules are in the syrup long before they are visible to the naked eye. These should consequently be fed so as to gradually force their appearance.

CURIN conducts the graining by successive introductions of syrup into the pan. If, after the first addition of syrup, the density is [$H-1°$ Brix.], after the second it should be [$H-\frac{1}{2}°$ Brix.], and after the third it should become H, the grain being visible; if not, another charge is necessary, and the density then is [$H+\frac{1}{2}°$ Brix.]. It is from this time forward that skill is required to obtain the standard granulation. The density then should be kept at [$H+2°$ Brix.], which is increased later to [$H+3.5°$ Brix.]. The mother liquor yields a large portion of its sugar; hence it is desirable to gradually increase the density, so as to favor the molecular attraction of the crystals it contains. By the intelligent use of the brasmoscope these variations may be followed and regulated, and the complete graining can be obtained in $3\frac{1}{2}$ hours instead of $4\frac{1}{2}$ hours, as is frequently the case.

For the practical working of the apparatus certain conditions are necessary. A special book must be kept, giving many details relating to each strike, the vacuo after each concentration, the temperature before new syrups are added, the density before and after, the density of the mother liquor before concentration, the quantity of juice added, etc. It must be noticed that the working of a vacuum pan has hitherto been too empirically conducted, and the results in nearly every case have not been what they should be. The pan man relies, when working under ordinary conditions, upon the general appearance of the syrup being boiled, and when the strike is finished the chemist in the laboratory can determine just within what limits the product corresponds to the demands of the market. As these requirements are constantly changing, the pan man has to do much experimenting before he obtains the standard grade of sugar that the manufacturer has sold in advance. This means a loss of time and money. Hundreds of empirical methods have proved most unsatisfactory from a technical standpoint, although certain scientific facts are well known.

CLAASSEN's apparatus (Fig. 140) has the same object in view, and its general outer appearance is very much the same as the brasmoscope. It consists of two fixed scales, L and T, giving the tem-

perature and the corresponding vacuum. Alongside of these scales are two others, the first, *D*, being divided into degrees centigrade of the same length as the division of *T*. The zero of this scale and the pointer, *C*, are placed upon a point of *L*, which corresponds to the customary vacuum, under which the pan is worked. On the other hand, the smaller pointer, *Z*, slides on the scale, *T*, at a height corresponding to the temperature of the massecuite. The scale, *D*, will give the difference in degrees centigrade between the two pointers; that is to say, the difference between the boiling point of pure water and that of the massecuite for a known vacuum. On the other hand, the scale, *S*, fixed to the scale, *D*, will indicate the water percentage of the massecuite for the differences of temperature shown upon that scale. Consequently, if one places the pointer, *C*, on the number corresponding to the vacuum existing in the pan, and the pointer, *Z*, on the number corresponding to the temperature then in front of the pointer, *Z*, the water percentage of the massecuite will be shown on the scale, *S*.

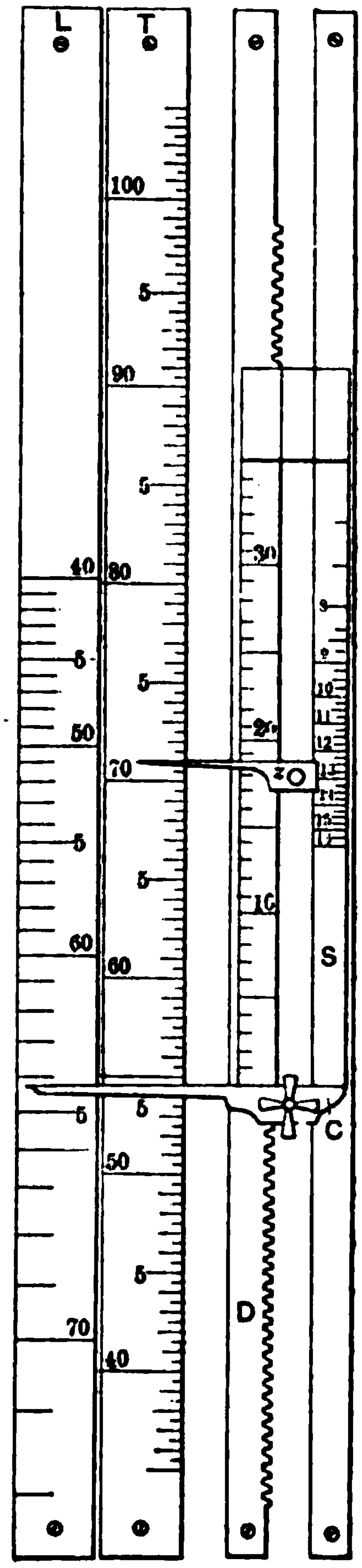

FIG. 140.
CLAASSEN'S Scales.

Reversely, it is easy to determine what temperature one should reach—supposing that the vacuum is constant—so as to obtain a given water percentage during graining, it being sufficient to place *C* on the number corresponding to the existing vacuo, the pointer, *Z*, upon the number corresponding to the desired water percentage (*S* scale), and to allow the temperature to rise to the degree on the pointer, *Z*, of the scale, *T*. If the temperature of the massecuite is lower, it will gradually rise through concentration; if too high, additional syrup is introduced into the pan so as to lower it.

CLAASSEN has constructed a table giving the difference of temperature between the boiling point of pure water and that of the massecuite, which should be maintained during different phases

of the graining. These different phases are indicated by letters from *a* to *h*. The letter *a* is subdivided into *a* and *a′*, depending upon the purity of the syrups. The phases that follow are divided into successive periods.

DIFFERENCE OF TEMPERATURE BETWEEN THE BOILING POINT OF PURE WATER AND THAT OF THE MASSECUITE TO BE MAINTAINED DURING DIFFERENT PHASES OF GRAINING (CLAASSEN).

Temperature of the graining.	During grain formation. Purity of syrup.		At once after grain formation.		During grain feeding.			During tightening.	
C°	*a*	*a′*	*C*	*c*	*d*	*e*	*f*	*g*	*h*
67½	17¼	18	20¾	20¼	19½	18¾	18	17	16¼
70	16¾	17¾	20¼	19¾	19	18¼	17½	16½	15¾
72½	16½	17¼	20	19¼	18½	17¾	17¼	16¼	15¼
75	16	16¾	19½	19	18	17½	16¾	15¾	15
77½	15½	16¼	19	18½	17½	17	16½	15¼	14½
80	15¼	15¾	18½	18	17¼	16½	16	15	14¼
82½	15	15½	18¼	17½	16¾	16	15½	14½	13¾
85	14¾	15¼	17¾	17¼	16¼	15½	15	14	14¼

TOURNEUR's method for graining in pan is based upon specific weight during the entire period of the strike. The density is considered one of the most important factors, which in most appliances is only very imperfectly determined during the graining, and to ascertain the existing conditions at any instant it would be necessary to take samples from the pan at regular intervals and to examine them in the laboratory. The pan man can not be expected to take this trouble; he is content with the general aspect or finger test. The apparatus illustrated in Fig. 141 gives continuously the average density of the product being crystallized, and allows an automatic regulation of the flow of syrup into the pan, so that the density may be kept at a regulated standard. This apparatus is based upon very much the same principle as the density indicator of the same inventor.

The apparatus consists of a valve, *S*, placed in the distribution pipe, *G E*. This valve follows the up-and-down movement of the float, *F*, which in turn follows the level of the water placed in a receiver, *A*. The receiver, *A*, is combined with a second compartment, *B*, placed at a very much lower level; both are connected by pipes, *C M* and *D N*, with the vacuum pan, and are arranged so that the level of the water, and consequently the float, *F*, and the valve, *S*, follow the variation of the average density. When the specific

gravity of the product in pan increases, the valve S will rise; and when the density decreases, it will cut off all communication with syrup supply. When the appliance is regulated, the flow of syrup from G into pan will continue in such a way as to allow the density to remain constant. A screw, X, placed on the upper part of A,

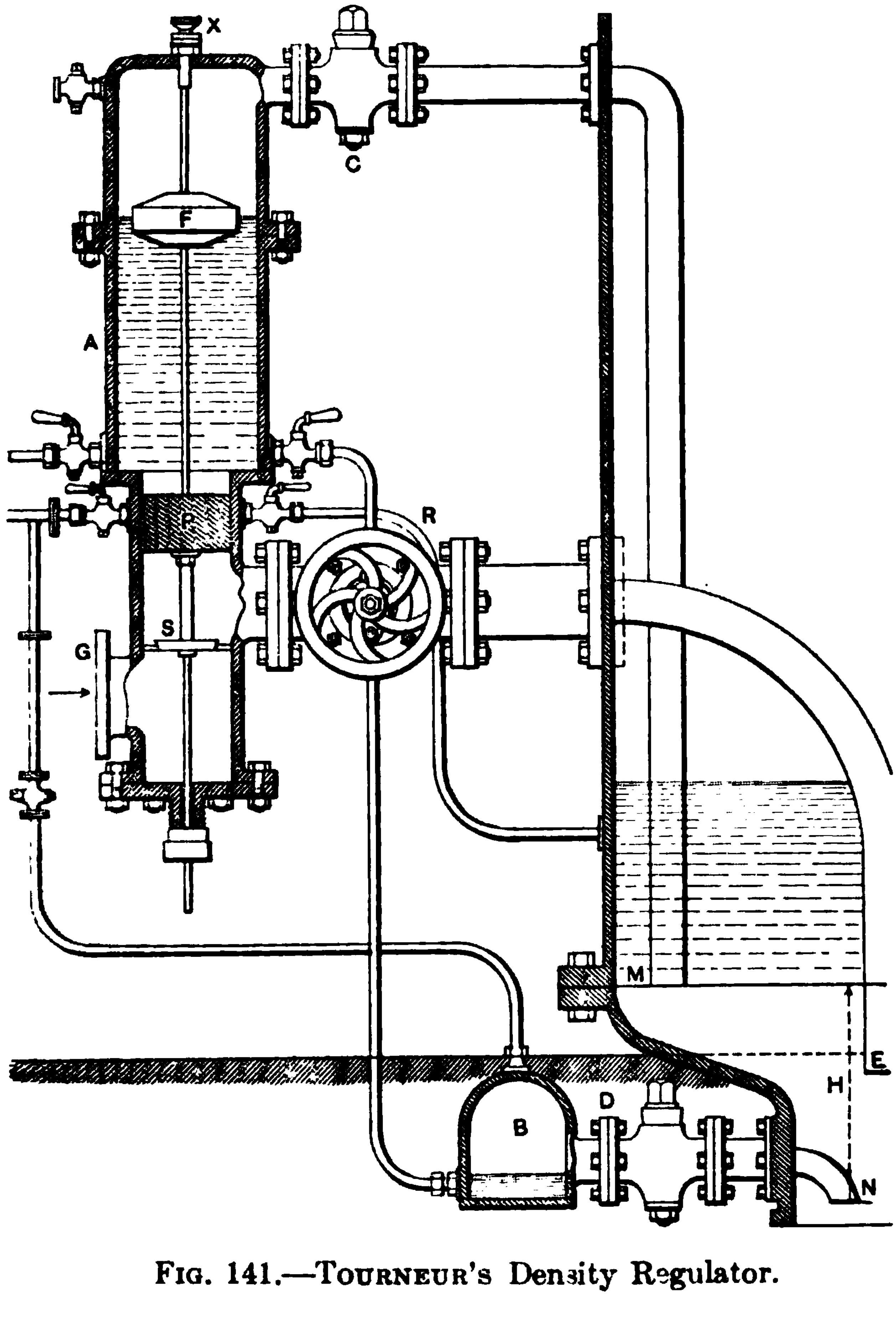

FIG. 141.—TOURNEUR'S Density Regulator.

allows the density to be regulated during working. It is claimed that the TOURNEUR appliance allows the graining to continue always under same conditions, and consequently to have a strike that is always perfectly uniform. As the syrup fed to pan is automatically regulated, there need be no fears of poor grain, the outcome of momentary inattention on the part of pan man. It is essential to

have M at a level below the principal joint of the pan, so that the corresponding pipe may penetrate the massecuite from the start. B must be always higher than N, and the vertical spacing between B and A should be such as to allow the difference in the water level of B and A to attain one and a half times the height, H.

DELAVIERRE's[1] experiments have the object of making the entire graining automatic. A special device renders the vacuum constant in the pan, under which conditions there are only two variable quantities, the pressure of the steam used for heating and the temperature of the graining, both of which vary from the same causes. The temperature of the massecuite and the pressure of the steam increase as the product being grained becomes more concentrated. These two factors decrease when the concentration of the massecuite is lowered by the introduction of syrup. An automatic regulator allows the syrup to enter when the pressure is excessive and the product is too thick.

On the other hand, if the steam pressure is lowered, this indicates that too much syrup was introduced, and under these conditions another regulator allows more steam to enter until its pressure is again within normal limits. The syrup is distributed, under considerable pressure furnished by a pump, throughout the entire mass, by a series of 15 injectors. The regulator of the syrup introduction also acts on the force pump.

From what has been said, it is evident that much yet remains to be accomplished before the results will be entirely satisfactory. Whatever may be the theory on which the graining is conducted, the practical automatic device has yet to be invented.

Perturbations during graining.—Numerous perturbations occur during graining. Sometimes these are readily overcome, especially when the irregularity is due to the faulty working of some other piece of apparatus upon which the pan depends.

Insufficiency of syrup.—When working the pan by the so-called continuous mode of graining, it is very important that there shall be no instant when the supply cannot be kept up. If the syrup waiting tank is becoming empty, the graining operation should be conducted more slowly than during regular working. If the waiting tank becomes entirely empty, the steam valve is closed and all communication with the condenser is cut off. The mass must be fluid, so that the sugar in supersaturation will crystallize very slowly.

[1] HORSIN-DÉON, Traité II, 2, 704, 1900.

The fluid massecuite, even if left to itself, will not readily crystallize when the steam valves are closed. There are certain emergencies in which this is necessary, for example, with a breakdown of the air or syrup pump, or when there is a bursting of a steam pipe. When the graining is first started, however, such stoppages are out of the question, and the best way is generally then to remelt all the grain in pan. If this measure were not taken, the result would be a mixed grain. When the strike has reached a certain stage the difficulty may, in a measure, be overcome by keeping the mass in motion, to which end a small air cock is opened upon the feed pipe through which the mass receives its syrup, and which should penetrate to the bottom of the pan. The bubbles find their way through the mass and produce sufficient motion to prevent the crystals from depositing. This method of air suction cannot be used if the condenser and air pump are out of order. The problem then is to maintain the existing vacuum as long as possible.

When an insufficient amount of syrup, at a time when the grain has been already formed in the mass, is the main cause of the perturbation, the strike may be concluded with diluted molasses. To attempt continuing the graining with carbonatation juices would be difficult in practice. In certain cases the semi-concentrated syrups, from the last compartment but one of the multiple effect, could be used. When the pan's working must cease for a considerable interval, during which the vacuum is lessened, all efforts should be centered upon tightening the emptying valves, etc., and sometimes it may be desirable to fill up the joints with putty or cement. In some emergencies, and in case an additional pan is at one's disposal, which is generally to be recommended, the semi-grained contents of one may be drawn into the other by allowing the vacuum to be more considerable in the pan to be filled than in that to be emptied. The graining then continues as usual in the other apparatus.

Difficulties in graining.—When handling syrups obtained from the juices of frozen beets, or when molasses has been introduced into the juices being carbonatated, the graining in pan offers certain difficulties, owing to the impurities present. The graining may be accomplished only by an exceptional concentration of the nucleus mass used as a basis of graining. If the steam used for heating exceeds a pressure of 0.5 of an atmosphere, there will necessarily follow a certain sugar destruction on the surface of the heating tubes.

Rather than resort to this exceptional concentration, which always involves a certain risk, all possible care should be given to the second carbonatation. The introduction of molasses should be given up, or else a high-grade second or third sugar is dissolved in the juices under consideration.

When such modes are adopted, difficulties during graining very seldom occur. It frequently happens that, during the operation of graining, certain changes manifest themselves, and the sugar crystals suddenly stop growing. The only remedy is to continue the strike slowly. Juices that have not been submitted to a proper manipulation during second carbonatation will frequently froth in pan. One of the remedies for this is to draw in a certain quantity of fatty substance which acts as a froth arrestor. According to CLAASSEN, the injection of live steam is of great assistance, and should be tried before using grease for this purpose.

STAMMER[1] declared that the principal difficulty in graining is caused by the pectates of lime, and suggested as a remedy any of the agents that will precipitate the lime, such as soda, sodic phosphate, oxalic and phosphoric acid. According to EISSFELDT,[2] difficult graining is due to certain germs. HERZFELD[3] favors this theory also; but BODENBENDER,[4] on the other hand, attributes the phenomenon to the presence of basic lime salts. RUMPLER[5] contends that 0.1 per cent of these salts is sufficient to cause difficulties during graining. According to LIPPMANN,[6] it is possible to prevent the formation of these salts by a careful defecation of the juices at a sufficiently high temperature; but, on the other hand, this same authority points out that there is no actual proof that the salts in question are responsible for the difficulty occurring.

CLAASSEN claims that the increase of calcic salts in the concentrated juice corresponds always to an increase in the percentage of organic substances due to the inferior quality of the beets sliced. He further says that an increase in the percentage of calcic salts does not necessarily mean a difficult graining in pan. Lime salts, that are the outcome of the destruction of invert sugar and nitrogenous substances through the action of lime, are not in the least objec-

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[1] LIPPMANN, Entwicklung, 164, 1900.
[2] Z., **27**, 64, 1877.
[3] Z., **41**, 44, 1891.
[4] Z., **33**, 630, 1883.
[5] D. Z. I., **19**, 1434, 1894.
[6] Z., **33**, 934, 1883. LIPPMANN, Entwicklung, 165, 1900.

tionable during graining, and have less influence in preventing sugar from crystallizing than have the organic potassic salts. It becomes evident that one cannot consider all the lime salts as causes of difficulties of graining in pan, and that the conclusions drawn from a high percentage of these salts regarding their action upon graining are not admissible. Certain organic substances, possibly coming from poor beets partly combined with lime, upon being dissolved in the diffusion battery, are responsible in a large measure for difficulties in graining. Their amount evidently increases when working slowly and at high temperatures. The rapid handling of the battery would, in a measure, obviate the difficulty. The longer the duration of diffusion the greater will be the dissolution of these objectionable salts, and for this reason the last strike of the week is generally the most difficult.

As a remedy for the difficulties in graining, besides the modifications in the work of the diffusion battery, the addition of soda or bisulphid of soda is proposed, in order to transform the organic calcic salts into corresponding sodic salts. The best results are obtained by adding the sodic salts to the concentrated juice, or even to the juice before its entrance in the multiple effect, so that the carbonate or sulphid of lime that precipitates may be eliminated through filtration. It is not, however, essential to transform all the calcic salts present by the means of sodium salts. CLAASSEN says that when this mode proves efficacious, a quarter or a half of the quantity of soda needed, as determined by theoretical calculation, overcomes the difficulty. It would seem that the objectionable calcic salts are transformed at the start.

Too much reliance cannot be placed upon this method, for even the authority who suggests it points out that it has not yet been demonstrated that sodic salts do not cause even greater difficulty during graining than the calcic. In this case VON LIPPMANN [1] recommends that defecated juices be boiled for half an hour before carbonatation.

CLAASSEN says that another method rendering excellent service in cases of difficult graining is a mechancial agitation of the mass, this being accomplished in pan by means of live steam freely introduced through distributors placed at the bottom of the apparatus. One may inject into the mass being grained as many steam bubbles as desired. The motion they produce renders the heat transmission and crystallization most satisfactory.

[1] D. Z. I., 8, 1161, 1883.

Sometimes the syrups have an excessive alkalinity. Concentrated juices that have not been sufficiently saturated, and consequently contain lime combined with sugar, are most difficult to grain properly. For this if for no other reason, the saturation in question should be carefully and thoroughly effected. As the lime saccharate is such an important obstructor in working the syrups in vacuum pan, the conclusion appears justified that, among the various salts known to exist in concentrated syrups, the calcic salts of acids having a high molecular weight, such as those derived from pectic substances, are more responsible for the trouble than any others.

Some syrups it seems almost impossible to grain, notwithstanding all efforts to overcome the difficulty. A remedy proposed by MARGUERITE[1] consists in introducing into the pan a small quantity of hydrochloric acid diluted in twenty times its volume of water. This operation demands very much care. The acid is introduced into the massecuite until its alkalinity drops to about 0.1 per cent of quicklime. While the difficulty may, in a measure, be overcome, new complications present themselves because of the introduction of foreign substances in the mass being crystallized, which necessarily have an important influence that must be considered. VIVIEN[2] recommends that carbonic acid be introduced into pan for the purpose of precipitating the lime. This idea is a good one, but it remains to be proven within what limits it can be practically carried out.

Difficulty during graining may be due also to the fact that the valve of the condensed-water purger is stuck on its seat, or that the float connecting with it is out of order, in which case the condensed water can no longer run from the heating chamber. This should be looked after at once; but often the pan man, to save trouble, simply ties back the lever of the valve, which objectionable practice necessarily causes a great loss of vapor that should have been utilized in one form or another. It is desirable to have in reserve a float for this purger, that the requisite repairs may be rapidly made, and there are advantages in having a valve upon the pipe carrying the condensed water to the purger. Upon this pipe is placed another valve or cock through which the condensed water may flow during any interval of repairs. This cock should be opened only when it is absolutely necessary, and not, as is too often the case, to facili-

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[1] La. S. B., 3, 396, 1875. [2] S. I., 8, 578, 1874.

tate graining, as the pan man frequently argues. When handling a mass that is difficult to grain, it is very important to be careful of the manner in which steam is used, as the pressure can rise suddenly and may exceed the limit for which the heating coils are made.

Formation of crusts and balls.—If the vacuum pan is not properly cleaned hard lumps may form in the massecuite. They are produced at the commencement of the graining in pans in case the heating surfaces are not entirely covered with syrup. The uncovered heating portions, such as coils, etc., are constantly sprayed with the concentrated juice and the drops that remain on them crystallize and adhere strongly to the surfaces with which they are in contact. This condition becomes still more marked if there is a leakage of the steam valves.

In certain spots the adherence is so close that even when coming in contact with the boiling mass they are not detached. These crystallized drops cannot be dissolved, as they are constantly surrounded with supersaturated juice, and when the steam of the vapor used for heating is passed through the upper coils the deposits are burned and transformed into hard crusts, which are frequently abundant. They have a crystalline fracture and are found chiefly at the junction of the supports of the coils or in the angles. Owing to the variation of temperature, especially when the steam is first introduced, these crusts or lumps frequently detach themselves after having reached a certain thickness falling into the massecuite, and are often found in the sugar. The larger portions alone may be removed, while the smaller crusts remain.

Hard balls of massecuite may also form at the lower part of the vacuum pan when the steam coils or pipes are placed too near together. Under these circumstances the motion of the massecuite is more or less paralyzed, and the product is burned on many portions of the heating surface. It is evident that these balls are formed during graining, and not afterward, as their interior surface is shiny and shows the exact convexity of the surface with which they were in contact. The crusts that form at the upper part of the pan generally show a fine crystalline texture, while the lumps of massecuite formed between the coils are made up of large crystals.

In order to obviate the formation of these crusts, or rather to prevent their passage into the raw sugar, the deposits formed on the coils should be redissolved after the strike has been emptied from the pan and before a new graining is commenced. It is im-

possible to dissolve them in concentrated juice, as it concentrates so rapidly as to prevent all dissolution. It is for this reason that CLAASSEN recommends that perforated steam pipes be placed below the heating surfaces of the pan. These project steam against the coils thus dissolving the crusts formed. The vaporization by use of the perforated steam pipes should continue for the period necessary to completely detach the crusts, and they will offer no difficulty in the subsequent operations.

The injected-steam method recommended by CLAASSEN prevents the formation of lumps at the bottom of pan, and, furthermore, when the vacuum pan is heated with steam coils or tubes that are too near together, the steam should be injected from perforated coils placed in positions which will allow the projection from bottom to top.

Sugar destruction.—The authorities do not agree in regard to sugar destruction during graining. Experiments[1] demonstrate that it is a mistake to continue graining for too long a period, as a certain percentage of sugar is destroyed, the viscosity is increased, and the alkalinity diminished, while the ash percentage remains unchanged. It is claimed that after five hours the destruction[2] is 0.23 per cent and after 8 hours 0.49 per cent. BATTUT[3] declares that during graining of first sugar the destruction is 0.286 per cent of the total sugar originally contained in the beet.

DEGENER and LACH[4] proposed to decrease the temperature during graining by increasing the vacuum, in order to decrease the percentage of sugar destroyed. SEYFERTH[5] attempted to obtain the same results by using exhaust steam and very large heating surfaces. PIEPER,[6] in 1882, also proposed that the duration of the graining be lessened by the use of mechanical agitators.

According to CLAASSEN, a destruction of sugar during graining is practically inconsiderable by the present methods of graining. As, for the reasons explained in the foregoing, the effort is made, and is nearly always successful, to produce a sufficient motion in the massecuite in the vacuum pan and upon the heating surfaces, there will exist in no portion of the mass an elevation of temperature, even when heating by old methods with live steam. Just as in the multiple effect during boiling, the temperature of the massecuite on top and on the bottom is about the same, and it is

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[1] Oe.-U. Z., **27**, 790, 1898.
[2] Bull. Ass., **16**, 781, 1899.
[3] Z., **42**, 818, 1892.
[4] Z., **32**, 574, 1882.
[5] Z., **20**, 742, 1870.
[6] Z., **46**, 41, 1896.

only in an apparatus of exceptional height that a difference of 1° to 2° C. exists. With a vacuum of 55 to 65 cm., the massecuite during the tightening has a temperature of 80° to 85° C., and at that temperature an appreciable destruction of sugar in alkaline massecuite is not to be considered. If one admits that particles of the product may momentarily take a higher temperature than that of the massecuite considered as a whole, this may, at the most, attain the temperature of the vapor or steam used for heating, and this vapor is at a maximum temperature of 115° to 120° C. in cases where vapors of evaporation are used. That is to say, the maximum temperature reached is one at which large quantities of sugar cannot be destroyed.

Certain practical observations which have led to the contrary conclusion are apparently accurate only in exceptional cases. When there is sugar destruction there is a marked decrease in the alkalinity of the mother liquor, for the reason that one part of the sugar destroyed will saturate 0.4 part of potassium or 0.25 part of lime. Such decreases in the alkalinity do not take place, and the slight change noticeable may be attributed in most cases to the decomposition of non-sugar and the liberation of ammonia. If one grains a neutral or acid-concentrated juice for any considerable period sugar may be destroyed, provided there is a high temperature of the mass and of the vapors used for heating.

Losses due to mechanical causes.—According to Bouillant,[1] at the beginning of the graining there is a comparatively small quantity of sugar carried off by entraînement, while the reverse is the case toward the end of the strike. This authority maintains that there is a mechanical loss of 0.1 per cent of the total sugar originally existing in the beet. According to Claassen, however, with normal methods of graining there are no mechanical sugar losses in pan through entraînement, and fine drops are never formed at the expense of the viscous massecuite to be carried forward with the vapors. There are, however, large detached lumps that follow the rise of the steam bubbles to the surface of the boiling mass, but which by gravity at once drop back into the strike. As long as the juice is being concentrated, that is to say, as long as the mass continues to be only slightly viscous and small drops are formed, the free space in pan is sufficient, and a very great amount of free space is not under normal circumstances necessary when

[1] Bull. Synd., 25, 756, 1897.

the strike of a massecuite is nearly finished. However, one should allow for the free space a height of 1 to 2 meters above the highest level of the product being worked in pan.

In exceptional cases there may be produced excessive frothing, or with normal juices this is produced when the vacuum rapidly rises, for example, after a perturbation in the working of the condenser (due to the absence of water) or of the air pump. In this case the massecuite, heated at a higher temperature corresponding to a greater vacuum, will suddenly abandon its excess of heat by the formation of numerous bubbles. In such cases the greatest prudence is necessary to prevent a portion of the massecuite from entering the vapor passages, through which it would be carried to the condenser. As a means of preventing this entraînement of the froth, air may be permitted to enter the pan in order to lower the vacuum, closing the sluice valve of the passage toward the condenser and gradually opening it to allow the vacuum to slowly rise in the apparatus, at the same time introducing a certain amount of oily substance upon the surface of the mass until the boiling is quiet and regular.

When the catch-all is working with regularity, the sugar loss by entraînement from pan can never be very great. Unfortunately, however, the return pipe for the collected sugar is frequently stopped up by the massecuite carried forward by the steam bubbles toward the end of strike. It is well to make repeated examinations, and if the return pipe from the catch-all is at the same temperature as the vapor pipe itself the conditions may be considered normal and there is no clogging.

Sugar losses may also be caused by steam coils or heating tubes that are not sufficiently tight, and these losses may be greater than in the multiple effect, as each time the pan is emptied the massecuite penetrates through the cracks into the heating chamber and into the condensed water. For this reason it is desirable to make repeated sugar tests of the condensed water, especially when the vacuum pans are started.

Important leakages of the heating surfaces are made noticeable during graining by the condensed water passing into the massecuite, which increases the time required for the strike owing to the slowness of the grain formation.

Repairing pan.—However slight may be the leaks in question, they are always manifested by characteristic sounds in the pan at the time of tightening the strike. If these are slight no attention

need be paid to them, but should they be of considerable importance it may be necessary to empty the pan entirely and to continue the operation in another apparatus.

The making of urgent repairs necessarily demands that the mechanic enter the interior of the pan, and certain precautionary measures must be taken. To cool the coils cold water is circulated through them. For this purpose one uses the water valve by means of which the coils had been submitted to a hydraulic test before the sugar campaign commenced. The bottom valve is opened, and, last of all, the valve connecting with the condenser is opened a fraction, so as to circulate some fresh air into the apparatus. If the emptying valve is too near the crystallizators and the air drawn in is too hot, air may be introduced by any other orifice, such as the manhole, observation windows, etc. When the apparatus is sufficiently cooled it may be entered, but as long as the repairs are in progress the pan should be watched; otherwise there is danger of an accident.

Small leaks in the coils of the vertical pans may be soldered with tin; but, on the other hand, if they are large the entire coil must be removed. In the case of horizontal pans such accidents are very much more readily repaired than in the vertical apparatus, and the tubes may be removed in a few minutes. Before the regular working of the pan is resumed, care must be taken that the repair man is out of the pan, and, furthermore, that all nuts have been tightened and no tools left behind, for the latter would cause destruction during crystallization in motion and curing.

CHAPTER II.

MANUFACTURE OF RAW SUGAR.

Preparation of the massecuite for curing.—The sugar crystals are freed from the adhering syrup through the action of centrifugal force. By early methods, now almost entirely obsolete, the massecuite was grained to the thread test, and run into small pentagonal boxes introduced in the sugar manufacture by SCHUEZENBACH. A bottom plug was removed and the mother liquor or syrup drained off. This process disappeared when centrifugals came into vogue.

Working with massecuite reservoirs.—The reservoir method consisted in running the entire massecuite into sheet-iron tanks. The product was allowed to cool, so that the sugar in state of supersaturation in the mother liquor would feed the existing crystals and help them to grow. Unfortunately, this increase in size was very slight and the greater portion simply separated as false grain. The solidified mass was removed from the reservoirs with shovels, or in some similar way, and was then broken up in special mixers before being run into the centrifugals. It is impossible to describe the dirty work which this process entailed.

The DENIS-LEFEVRE combination (Fig. 142) shows a progress upon that primitive mode. The drawing explains itself. The massecuite tank has a slanting bottom. When the proper moment arrives the sluice, *S*, is opened and the product falls into the crushers, *C*, beneath and is then drawn through the ball valves and forced up through a pipe, as shown by the arrows, when it falls into a hopper connecting with the centrifugals. There is no shovelling, and that section of the factory can be kept comparatively clean, which with the old methods was out of the question. Furthermore, fermentation frequently occurred, involving sugar losses.

The massecuite mixers are of varied construction. In Figs. 143 and 144 are shown the SELWIG and LANGE mixer, consisting of a horizontal drum, having attached to it a series of knives, straight

or curved, arranged spirally. The entire system has a slow revolution in a suitably arranged iron trough, over which is a hopper.

FIG. 142.—DENIS-LEFEVRE'S Handling of Massecuite.

Movement is given to the apparatus by pulleys on the main axis, the latter being connected with the upper axis by gear wheels.

FIGS. 143 and 144.—SELWIG and LANGE Mixer.

When the mass is thrown into the hopper the first breaking up occurs while passing through the two upper serrated rollers. When the mixing is finished the apparatus is emptied by opening a valve

at the bottom, and the product falls into small wagons running on rails over the centrifugals. To facilitate the operation a certain quantity of water or diluted after-product may be added.

Schuezenbach's boxes.—Instead of massecuite tanks many factories formerly used small, movable boxes called SCHUEZENBACH boxes after those previously mentioned. Notwithstanding the fact that they had numerous advantages over earlier devices, they are being used less and less, and more modern appliances are taking their place. The boxes shown in Fig. 145 are comparatively high, and are wider on top than at the bottom. They will hold as much as 500 kilos of the product. In the bottom of the box is a hole, which is closed with a suitable plug, and on the sides are two journals resting on two stirrups, which are supported on the frame forming part of two wheels. These, with the tiller, constitute a small carriage which may be readily moved from place to place. A number of men present these movable boxes under the hoppers from the pan, and they are rapidly filled with massecuite. In case the product is very fluid certain precautionary measures should be taken to prevent the men in charge from being burned.

FIG. 145.—SCHUEZENBACH Box on Wheels.

These receptacles are placed side by side in a large room where they may cool, and, as they occupy considerable floor space, they should be as near together as possible. In some factories they used to weigh each of these receptacles on scales, but as by present modes of working this would be a waste of time, the mills still using these boxes take the average weight of three or four of them. The period of cooling is variable, depending upon the quality of the massecuite. In pure massecuite the mother liquor has a comparatively high purity and will rapidly crystallize in 12 hours, provided the cooling room is at 25° C. Theoretical results, however, are not obtained in practice. The cooling is not uniform, and considerable false grain is formed. The portions in contact

with the iron sides are comparatively cold, while in the centre the mass is warm and fluid.

When these boxes are filled from pan on the same floor as the centrifugals, they have to be raised on a lift to a floor above that on on which the mixers are located. When sufficiently cool and hard the product is emptied into these appliances and crushed. To facilitate the emptying the bottom plug is removed and replaced by a rubber pipe, through which compressed air is introduced, and the entire mass is soon emptied. This way of emptying was first introduced by BECKER.[1]

When it is the intention to work the mass hot in centrifugals it is simply run through the mixer; if it is desired to cure it at a ow temperature, molasses at 35° Bé. is added to prevent the breaking of the crystals. The temperature and dilution of the after-product used depends upon the degree to which the massecuite has been cooled. If a considerable quantity of false grain has been formed the curing cannot be readily accomplished, and it becomes necessary to add so much diluted hot molasses that the small crystals will redissolve. There is no standard by which one can determine in advance the quantity of after-product to be used. In most cases too much diluted molasses is added. The working with these boxes demands care, otherwise, as has been previously pointed out, the floor of the room will be in a filthy condition.

Artificial cooling.—To overcome these difficulties BOCQUIN and LIPCZINSKI have introduced an apparatus which rapidly cools the massecuite, so that it may be satisfactorily cured in the centri-

FIGS. 146 and 147.—BOCQUIN and LIPCZINSKI Refrigerators.

fugals. The product is kept in motion and does not form a compact mass. This apparatus (Figs. 146 and 147) consists of a semi-cylindrical trough with raised sides which are double, so as to leave

[1] Z., 23, 223, 1873.

a space for the circulation of cold water. Upon the axis, *bb*, are the agitating arms, *c, c, c*, arranged in a spiral, by which means the massecuite is continuously brought in contact with the cooling surfaces. The motion is given from a horizontal screw, *e*, that gears with *a*. The apparatus is emptied from the bottom. It was very simple in construction, needed very little looking after, and it was claimed that it required no diluted after-product, as does the SCHUEZENBACH method.

Experience has shown that numerous difficulties arose from the very fact that the diluted after-product was not added as the cooling progressed, and in the factories where this apparatus was used the custom was to resort to this addition, water being frequently used instead of molasses. Since the crystallization in motion has come into vogue, which will be discussed under another caption, this method is being abandoned. Numerous appliances of the same kind have been used. The arrangement does not much matter, as the final result is always about the same. The motion should always be very slow, not more than two revolutions per minute, and requires very little power. A thermometer should be within easy reach, so that the temperature may be kept under perfect control.

In most beet-sugar factories there are two coolers for every vacuum pan. As the strike in pan lasts about 10 hours, the cooling may continue for 15 hours, after which period it may be satisfactorily handled in the centrifugal. However, in many cases only 10 hours are allowed for this operation. Under all circumstances the coolers should remain empty at least two hours before the new strike from pan is emptied into them. When the massecuite presents a viscous appearance, which always is followed by difficulties during the curing, this operation should be started earlier than usual, in order to prevent delays in the other stages of sugar extraction. These coolers should be filled to within 100 mm. of the top, so as to leave room for the diluted after-product or water to be added. It is important that the agitating arms shall not pass outside the upper surface of the product being cooled, as a portion would be lifted to subsequently fall back and carry with it air bubbles, which, in excess, would seriously delay the curing. For the same reason the remains of a strike should not be emptied into the refrigerators unless the volume is sufficient to fill the receptacle. It would be far better to cure the excess of massecuite if it does not fill the cooling mixer without attempting the cooling.

By the ordinary method of mixing the regulation of the temperature, the first essential for a good crystallization, cannot be controlled. After the massecuite leaves the pan it is cooled rapidly, so as to bring it to a temperature that will give the best results, water or diluted after-products being added during its curing. The working with mixers has an advantage as regards cleanliness over the use of boxes, but, on the other hand, the yield of sugar by the latter method is greater than by the mixing process, and the after-product, consequently, has a lower purity. With these coolers it is possible to lower the purity of the mother liquor to 74 or 75.

There can be no question but what a regulated crystallization of the massecuite is obtained when it is emptied into boxes or mixers. The only precaution necessary is that the cooling be gradual. There will follow a crystallization from the mother liquor upon the crystals already existing, and upon the new small crystals which were formed during the tightening operation after graining, or during the cooling. These crystals can only be partly collected during the swing-outs in centrifugals. The principal object in working a massecuite is to extract the largest possible amount of sugar, which is not realized by the work in boxes or during mixing. The object for the present is to put the massecuite into a condition that will facilitate its swing-out in centrifugals.

Care needed.—Although these coolers need little or no care, the horizontal screw through which the motion is transmitted should be kept well oiled, and precautions should be taken not to allow any hard substance to fall into the mass, as this would cause some breakage. The emptying valve or gate should remain open as long as possible after the apparatus has been emptied of its contents, and the valves should be washed with hot water before closing it and refilling, otherwise they will stick.

Advantage.—There are numerous advantages in working by this cooling and mixing method, among which may be mentioned economy of labor, easy control, exceptional cleanliness, and facilities for obtaining a massecuite in that condition in which the curing in centrifugals may be very advantageously done.

Transportation of massecuite to centrifugals.—The cooled massecuite may be transported to the centrifugals in various ways: by cars running on rails, by troughs with revolving spirals, chains with disk attachments, massecuite pumps, and by compressed air. The first plan is extensively adopted in Germany and Austria.

These cars come under the emptying gate or valve of the refrigerators and then roll on a trolley over a centrifugal, where they are

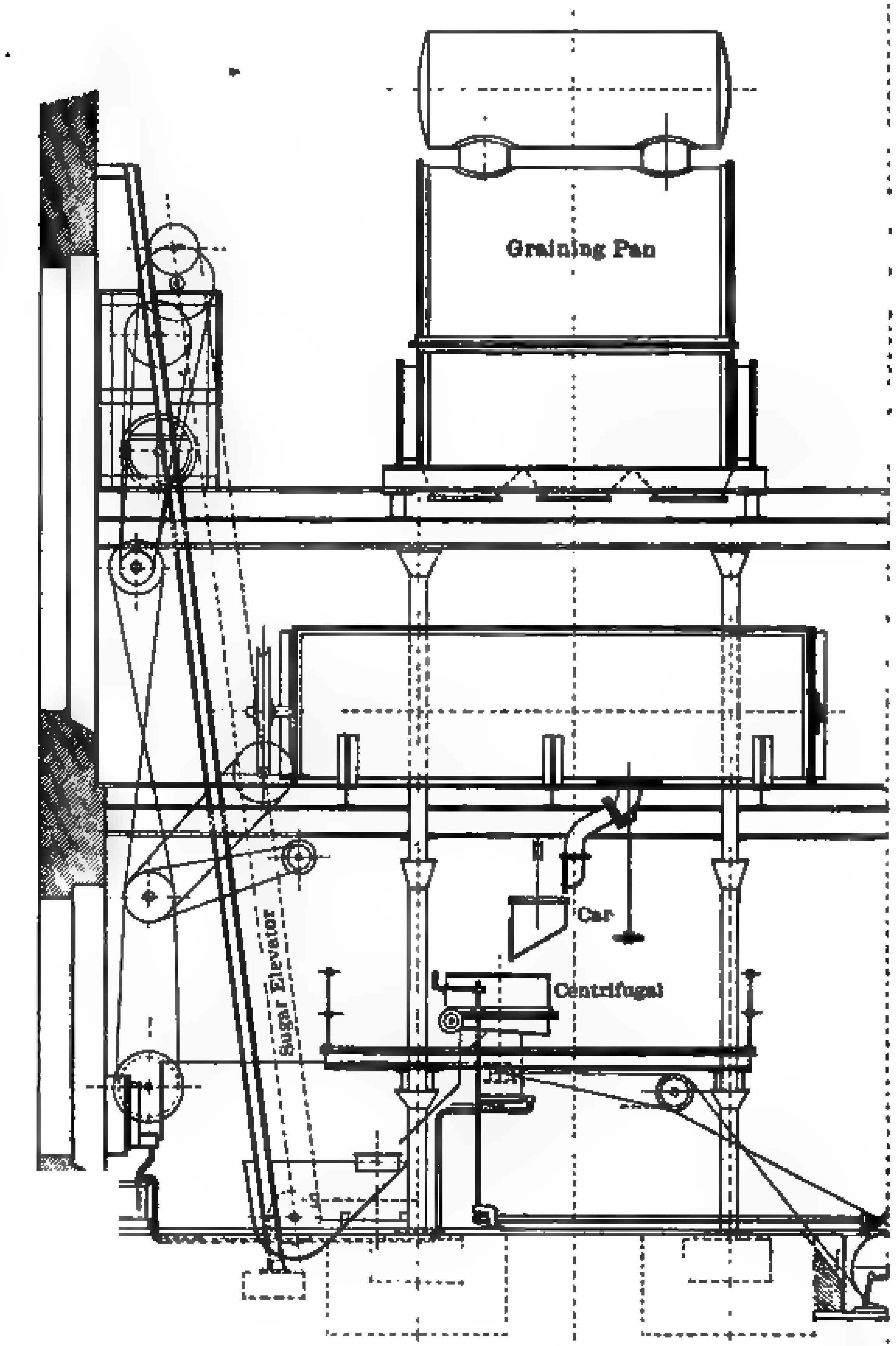


FIG. 148.

emptied of their contents. The arrangement of BREITFELD and DANEK is shown in Fig. 148. It is to be noted that this method of

transportation is dirty and demands considerable labor, but it permits one to ascertain exactly the quantity of massecuite being handled, and this may in certain cases be very advantageous, especially when the curing is difficult and the load has to be reduced. There is very little cooling during this transportation.

The HEPWORTH distributors with mechanical agitators were made known in Continental Europe by WUNDRAM,[1] but underwent several modifications. The agitators adopted to force the massecuite along in the troughs have been most varied in shape. In Fig. 149 is shown one of these arrangements, in which *a* is the trough

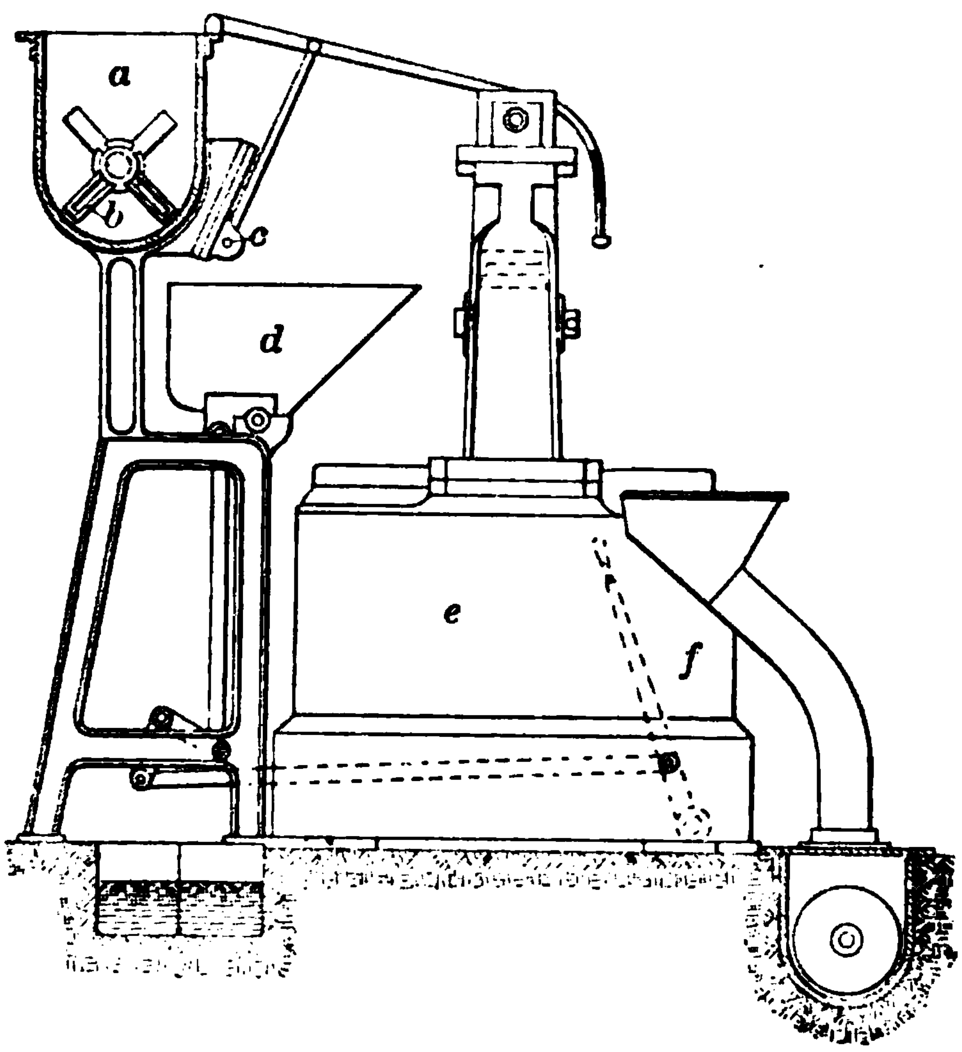


FIG. 149.—Massecuite Distributor and Mixer.

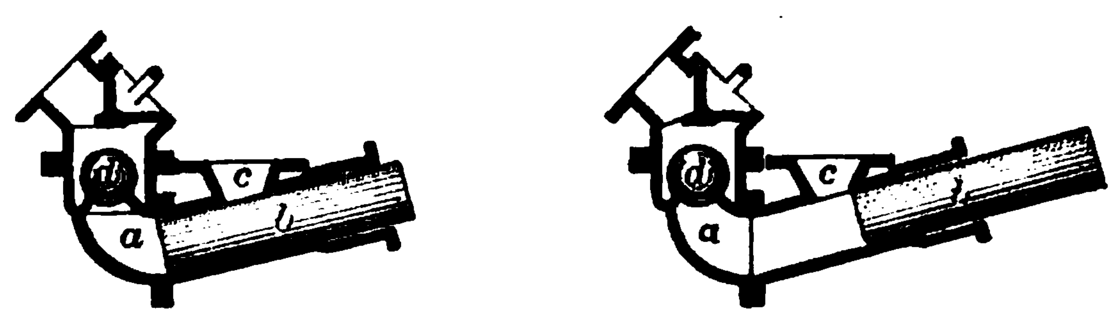
where the massecuite circulates, and *b* the agitator. The register, *c*, allows the measuring hopper, *d*, to be filled, its centre of gravity changing during the filling, and after the conditions of stability cease to exist it tips over and its contents are emptied into *e*. The lever, *f*, permits *d* to be replaced in its original position. In most cases this measuring hopper is done away with and the product from *a* falls directly into the centrifugal. This apparatus is no cleaner than the suspended cars, but its working is more economical, as the labor for operating the cars is eliminated. One objectionable feature, however, is that the trough must be full, as otherwise the agitating arms would introduce considerable air into the mass.

[1] Z., 25, 131, 1875.

When the swing-out operation is finished there always remains in the troughs a certain quantity of the mass which soon hardens, the crystals formed being crushed as soon as the agitating arms are set in motion. Better results are obtained by having double-bottom troughs through which steam circulates, notwithstanding the fact that there is no special advantage in heating the first massecuite before its swing-out in the centrifugal. But in case the product is not readily worked in centrifugals, or that it remains in the trough for a considerable time, this heating is to be recommended. The filling of the centrifugals is a question of practice. No rule can be given as to the volume of massecuite to be cured. If the centrifugals are filled when at rest, which is generally the case, one may obtain a satisfactory filling by having some convenient mark on the drum of the apparatus, to indicate the height which the massecuite should reach before the drum is made to spin. Even when the centrifugals are filled when working, which is the case when handling second and third massecuites, the persons in charge soon acquire the requisite dexterity for the work.

When it is desired to raise the massecuite from one of the distributors just mentioned an endless chain may be used. These chains have plate attachments that lift the product in a slanting gutter in which they move. It is very correctly pointed out that this procedure always crushes the crystals, and keeps the product exposed to the air for too long a period.

Massecuite pumps.—As early as 1884 the FIVE LILLE Company proposed that pumps be used for the transportation of massecuites. The SELWIG and LANGE pumps have been in public favor for a long time. Their general arrangement is shown in Figs. 150 and 151.



FIGS. 150 and 151.—SELWIG and LANGE Massecuite Pumps.

During the period of suction there is a vacuum created in *a* between the piston, *b*, and the bullet valve, *d*. When the space, *c*, is opened the massecuite will enter into the cylinder of the pump. When the motion is reversed the product is sent through the force pipe to the centrifugals. The efficiency of these pumps is comparatively small, owing to the fact that their actual working is only by a single

stroke. To increase the efficiency FESCA adds a slide valve, *S* (Fig. 152), that remains closed when the piston's direction is reversed. These pumps give equal satisfaction when used with the SCHUEZENBACH boxes and with the cooling and mixing apparatus.

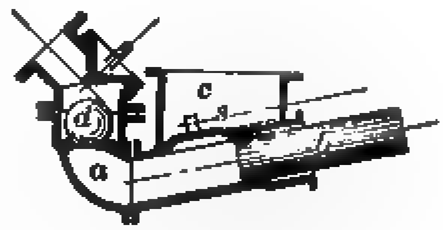


FIG. 152.
FESCA Massecuite Pump.

The FIVES-LILLE pump has some advantages (Fig. 153) over the arrangements just mentioned. It is combined with a mixer, *a*, from which the properly diluted massecuite is drawn into the cylinder of the pump when the piston, *b*, opens the space, *d*. The heavy valve, *c*, may be raised from the outside if it should become stuck on its seat. These pumps may force the product to where it is to be handled, or into suspended cars over the centrifugals, etc.

Satisfactory results have been obtained by the filling of the centrifugals with massecuite from a horizontal pipe with bottom openings corresponding to each centrifugal. To prevent the granulated mass from filling up the distributing pipe a chain moves backward and forward at regular intervals. The application of compressed air for the transportation of massecuites to the centrifugals demands that the apparatus from which it is forced be entirely closed and that the mass be very fluid.

FIG. 153.—FIVES-LILLE Massecuite Pump.

CHAPTER III.

CURING.

General considerations.—The massecuite consists of sugar crystals with a syrup or mother liquor adhering to their surface. To effect their separation the product is placed in circular baskets, to which is given a rotary motion that attains considerable velocity. The fluid portions are thus swung out during the spinning, and the solid portions, or sugar, remain in the interior upon the metal filtering sheet, the mesh of which varies with the work to be done. These appliances have taken the place of the old mode of curing, which consisted of a simple drainage in boxes of the SCHUEZENBACH model or other receptacles.

It was SCHOTLER[1] who, in 1844, made the first practical experiments to separate syrup from sugar crystals by the action of centrifugal force in special appliances. These early efforts did not meet with much success, and, according to TISCHBEIN,[2] it is to CLASE that the first practical results must be attributed. These were first obtained in the LEMBEEK (Belgium) sugar factory with a SEYRIG centrifugal; then with a FESCA[3] centrifugal with bottom driving. The apparatus in question consists of a circular basket, which receives its motion from the bottom by means of a belt, or from above through the intervention of a friction pulley. The drum has a perforated interior covering of sheet-iron or other metal, the meshes of which retain the sugar, while the exterior casing holding the drum is of sheet or cast iron and collects the swing-outs at the bottom, where there is an exit opening.

Foundations for centrifugals.—The outer casing rests directly upon the ground in case there is upper driving, or, in case of under driving, upon a foundation, protecting the organs of transmission, to which the centrifugals are directly attached by means of suitable bolts. The foundation should be solid and made of hard brick

[1] Z., 1, 225, 1851. [2] Z., 1, 209, 1851. [3] Z., 4, 93 and 300, 1854.

or stone and well cemented. In some cases the centrifugal rests upon iron girders, tightly held to the foundations, while in others a simple wooden frame is used. The WESTON centrifugal, generally used in America and the West Indies, is suspended to overhead beams.

The drum.—The basket or drum of the centrifugal consists of a cylindrical receptacle having an upper border that is turned toward the interior of the drum. It is essential that the slant given to the border be kept within reasonable limits. In some cases it is riveted to the drum by means of an angle iron, but this arrangement has many objectionable features. Some experts claim that there are advantages in having the border form a winglet, upon which the perforated sheet may be soldered. Sometimes the drum is simply made of sheet iron.

The diameter of the old types of centrifugals was generally 750 mm., and they could handle a load of 75 kilos of massecuite. The more modern centrifugals have diameters up to 1250 mm. and will hold 500 kilos of the crystallized product. By their use considerable labor is saved. The height seldom exceeds 500 mm., for the reason that beyond this limit the product does not distribute itself over the entire surface of the drum. The surface of the mass then treated not being uniform, the color of the finished sugar will not be satisfactory.

The total pressure, P, upon the sides of the drum during its working may be calculated by means of the formula $P=\frac{mv^2}{gR}$, in which m = mass, v = circumference velocity, R = radius of the centrifugal, and $g=9.81$. It may be concluded that the centrifugal force is proportional to the mass, to the radius, and to the square of the number of revolutions.

The mesh of the **filtering sheets** should be only of moderate size, being sufficiently close together to allow a free exit of the swing-outs. Advantages are found in placing between the drum and the filtering sheet a wire cloth with a rather larger mesh of about 6 to 8 mm. There must be a limit to the size of the mesh, as when taken too large the inner filtering surface wears too much.

To facilitate the exit flow of the molasses, STOECKER [1] places under the filtering sheets of centrifugals a perforated metallic cloth, bent over several times, so as to offer the fewest possible

[1] D. Z. I., 27, 790, 1902.

points of contact with the inner filtering surface, which allows the swing-outs to escape freely. With the same idea in view, NEGRO[1] increases the number of holes in the drum. In this case the perforations are conical in shape, being larger on their inner than their outer surface, and so arranged that their borders are all tangent. It is evident, under these circumstances, that no portion of the inner surface of the drum offers greater facilities for the syrup or molasses to escape than the other.

For a satisfactory working in centrifugals the manner in which the metallic cloths of the revolving drums are perforated is of some importance. The filtering sheets are generally perforated plates of brass, the holes being conical in some cases, and the wider portions being on the outside. Sometimes preference is given to slits with outside enlargement. The most desirable dimension for these holes or slits should be determined at each sugar factory. There does not appear to be any special advantage in having conical holes. The main question is, the form and size of the holes or openings upon the interior surface.

The holes or openings in the cloths should be as small as possible within a reasonable limit, for if too small they will soon be closed by the crystals. These holes or slits are about one millimeter wide, depending upon the size of sugar crystals to be separated, and they must not be so numerous that the strength of the filtering sheet will be reduced. Many experts recommend that these sheets be rather thick, as they can thus stand very much more wear and tear. The metallic cloths formerly used had certain advantages, as the shape of the meshes prevented the crystals from presenting their flat surface, and thus clogging the passage of the syrup, but their cost and short life resulted in their abandonment. For example, those of LIEBERMANN[2] are said to have been put aside on account of their price. They were made in a very ingenious way, in one piece without a seam, and consisted of helicoidal wires twisted into one another. The ends were joined by running a wire in and out through the open mesh. MASSIGNON and DUFOUR estimate that the increase in yield was 3 per cent during the swing-out operation when these cloths were used. Preference seems to be given to brass for making the straining sheets. Copper has been experimented with, but was found to be too expensive and offered no advantage.

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[1] Z., 51, 564, 1901. [2] La. S. B., 11, 476, 1883.

Great care should be taken to keep these filtering sheets very clean. Should they have cracks, some of the massecuite will escape, and the sugar crystals that would otherwise have been separated find their way into the after-product. The slightest defect in the sheet should be repaired without delay, using for the purpose a simple solder. The pieces thus forming patches may reach considerable size, and the space taken up by the soldering means so much less filtering surface and forms so many dead spaces, as far as the efficiency of the apparatus is concerned. The filtering sheets are always a fraction larger than the surface of the circumference of the drum. When put into position the ends should lap and be tightly attached, so that they will not get displaced during the rotation of the drum.

The outer casing.—The outer casing of the centrifugal, as mentioned in the foregoing, is either of sheet- or cast-iron, and for the larger types of apparatus as now used preference seems to be given to rather thick steel plates, which are a partial protection against explosions. Centrifugals for raw sugar have top covers only in very exceptional cases. It is necessary that the top of the outer casing project inward and form an obstruction, so that, if a solid substance should find its way into the interior of the drum, it would not be swung out during the spinning. When this construction is not adopted, the centrifugal man often slides his hand or the shovel down between the drum and the casing to find whether the swing-out is finished, for there will then be no after-product separated. In the raw sugar centrifugal, steam is very seldom used. It may be advantageous to have a small steam pipe to heat up the massecuite if it has cooled and is difficult to work. The separate after-product escapes through one or more openings at the bottom of the casing.

The spindle.—The drum is generally wedged to the spindle by means of a conical attachment. The extremity of the spindle passes beyond the cone, and has a nut that tightens the one against the other. In the more modern centrifugals there does not appear to be the same stress placed upon the attachment between the spindle and the basket as formerly. When the apparatus comes to a standstill, there is a very great twisting strain upon the spindle. If the stoppage is too sudden, and the basket or drum is not wedged tight upon the spindle, it simply keeps revolving. The spindle of centrifugals driven from above revolves in a bearing attached to the frame of the apparatus. In some centrifugals driven from

beneath, a bearing is fixed to the bottom of the outer casing, and holds the spindle underneath the drum, but most of them have more or less movable bearings suspended on large tightening bolts. Between the nuts and the frame are placed elastic buffers that give a certain elasticity to the spindle. Great care should always be taken to properly regulate the spindle or axis on which the drum revolves. It should be perfectly vertical, and all the nuts on the bracing rods should be tightened under the same conditions, so that there will not be the slightest oscillation in the motion. If one portion is tighter than another, there will be a swing in that direction which increases with every revolution of the basket. The lower bearing of the spindle is a delicate part of the centrifugal. The pivot should be convex and carefully made. If too flat the friction is excessive and the bearing gets hot. The metal upon which the pivot rests should be of a kind and quality determined by experience, and when worn it should be replaced without delay. This care results in a saving in the power needed to run the apparatus. All these parts must be properly lubricated, but, do what one may, there is always considerable wear and tear in the bearing.

The brake used to stop the centrifugal frequently consists of a collar with leather or wood lining, which is pressed against a special crown fixed on the pivot of the apparatus. As a general thing, the collar consists of two jaws that are tightened by means of suitable levers. MALANDER points out that this arrangement is faulty, for the reason that the pressure is generally greater on one side than it is on the other, and there follows a deviation from the vertical which always results in certain oscillations that are not desirable. Furthermore, one must keep up the pressure exerted by the brake until the drum has come to a standstill.

For the top-driven centrifugals the CORSOL brake is much liked, and with certain variations is used on most of these centrifugals. It consists (Fig. 154) of two jaws, *A* and *B*, with wood mountings; these articulate around the pivot, *G*. It is provided with a spring, *F*, that may be regulated by the nut *E*. The distance between the jaws is regulated by the handle *D*. The maximum spacing exists when it is open. In other arrangements the jaws are opened or closed by means of a screw. These brakes stop the revolving drum gradually.

Several devices may be used to hold the levers of the brake in position after the pressure has been exerted, one of which is to

have a ring sliding on the levers. This is kept in position by passing on a notch on the surface. In some cases the brake does not work on the spindle, but upon the outer surface of the drum. This has the advantage of doing away with the strain upon the spindle, but cannot be applied to all centrifugals.

In the FREITAG[1] centrifugal there is upon the spindle a plate that rubs against a fixed plate which plays the rôle of a brake. Oil is forced under the spindle, and, as this is raised up, the two portions of the brake separate and the centrifugal revolves. To stop the apparatus, the oil-feeding is discontinued and the plates are brough t in contact with one another, their friction acting as a brake.

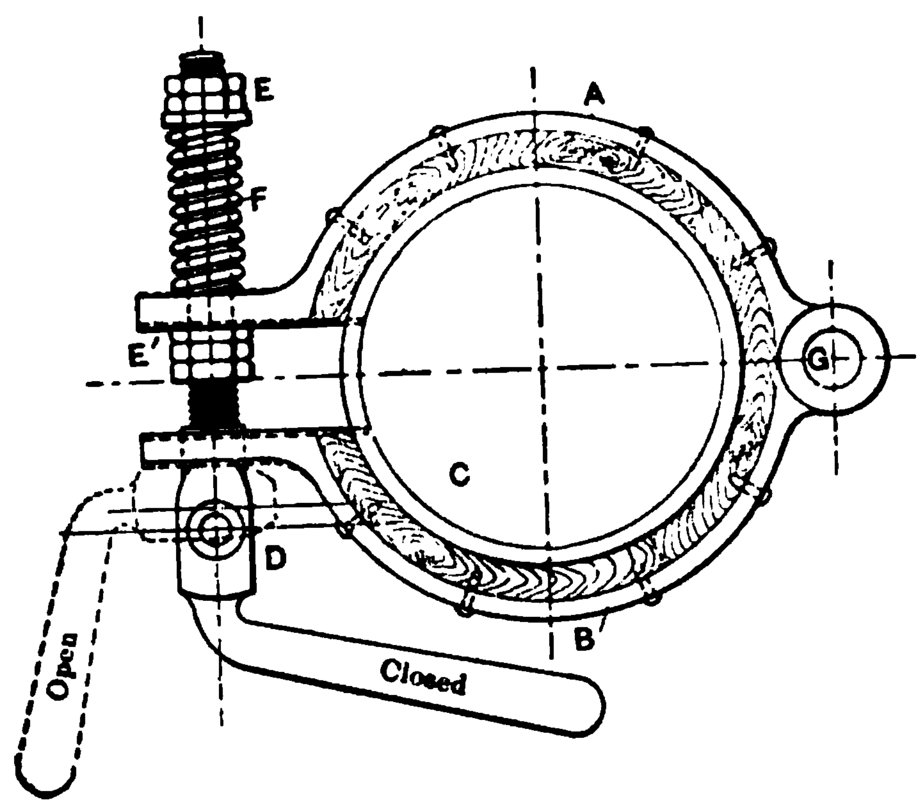

FIG. 154.—CORSOL Centrifugal Brake.

The oil thus forced into the bearing acts as a lubricant, after which it rises and lubricates other portions as well.

For the linings of brakes preference is given to some soft wood, such as poplar, which answers the purpose very much better than hard wood. Its fiber should be placed lengthwise, for if placed vertically the resistance offered is so great that the pressure shoes take fire. Under no circumstance should this brake-tightening be excessive.

Driving centrifugals.—Power is transmitted to the centrifugal by friction cones or belts, or directly from an electrical motor attached to the spindle itself. Of late years they have been driven by steam engines or by hydraulic power. The friction cones are generally on top, as shown in Fig. 155. In this case the drum consists of a perforated sheet-iron cylinder fixed upon a vertical axis,

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[1] Z., 53, 236, 1903.

the upper end of which is the friction cone, *C*. The drum revolves in the interior of a cast-iron casing, with a bottom exit opening, *O*, for the escape of the swing-outs. The cast-iron frame is surmounted by an arch, *A*, holding the driving axis, *H K*, and the top bearing of the spindle *D C*. This spindle has also a brake, *N*. The cock, *L*, and the pipe, *M*, are for the introduction of moist air, water, or steam into the drum. The belting on the fixed pulley, *F*, is used to start this centrifugal. The two friction cones are brought in contact by turning *K*, and the spring, *G*, keeps them tightly against each other. This apparatus is brought to a standstill by turning *K* in the opposite direction and tightening the brake, *N*. These friction cones are made of compressed leather or cardboard especially prepared or silicated. The disks are cut of different sizes, glued together, dried, and then turned on a lathe. The advantage of the silicated cones is that they are strong, and will withstand the hot and moist atmosphere of the centrifugal rooms. The starting of a centrifugal should be gradual, so as to obviate excessive wear of the friction cones.

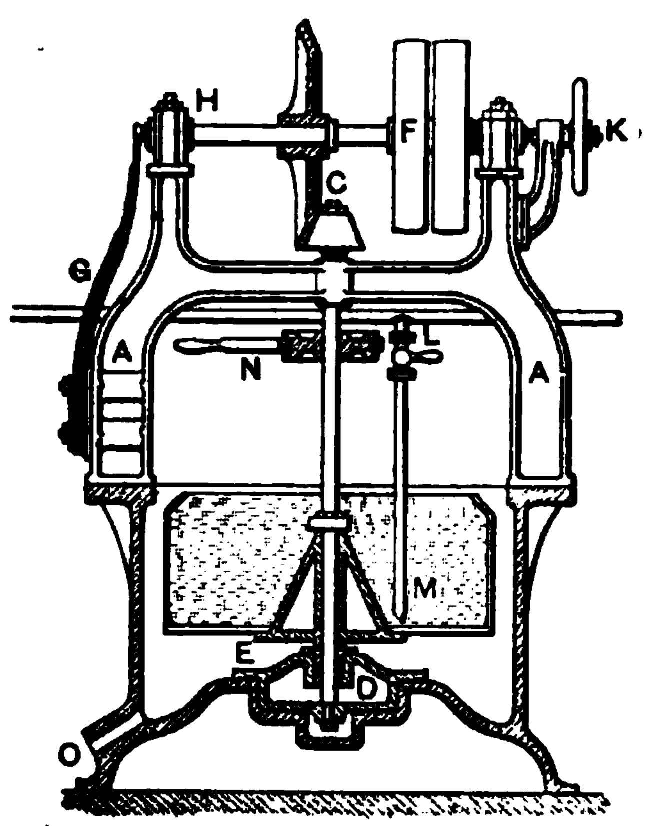

FIG. 155.
Top-driven Centrifugal.

Suspended centrifugals.—Among the upper belt-driven centrifugals are many different types of suspended apparatus, such as the WESTON, HEPWORTH, etc. Fig. 156 gives a general idea of the LAIDLAW suspended, over-driven centrifugal, which is one of the numerous WESTON varieties. The drum, *d*, is suspended to the girders, *ee*; a belt passing over the pulleys *a* and *c* does the driving. The trolley, *b*, does away with the fixed and loose pulleys. The basket of this centrifugal can oscillate within reasonable limits, so as to displace the center of gravity when the load is irregular. It thus finds the centre of rotation that is most suited to its spinning. The method of controlling the oscillation is made evident in the section of a spindle and driving pulley shown in Fig. 157. *B* is a bracket bolted to the upper beam that holds the spindle, *S*, and between the two is an elastic buffer, *I*. The spindle itself does not move, but at its bottom is the revolving bearing, *F*. It is enclosed

in an outer spindle, and between the two there is an attachment by a pin. The elastic buffer permits a slight swing, of which men-

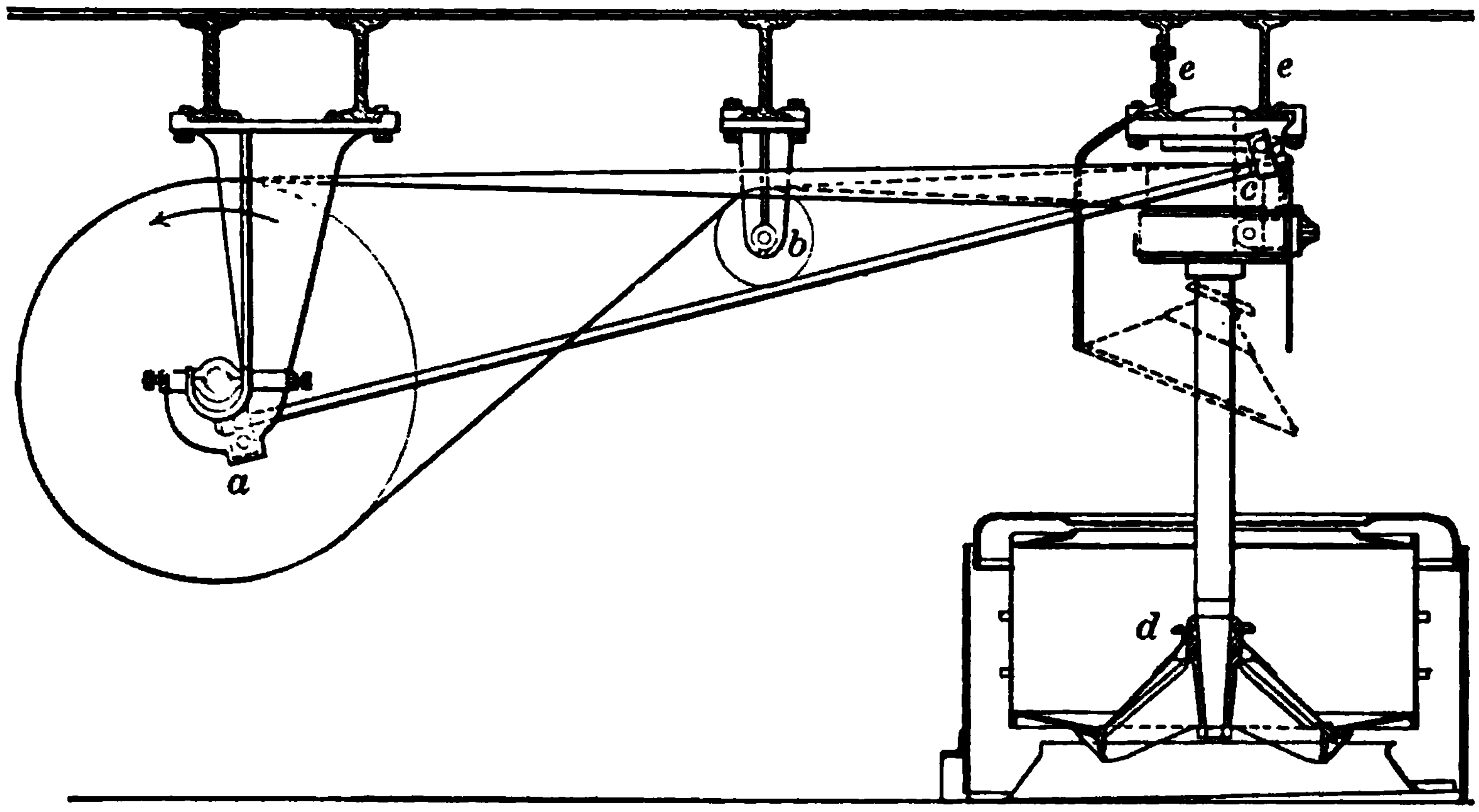

FIG. 156.—LAIDLAW Over-driven Centrifugal.

tion has been made. The pulley, *P*, drives the exterior spindle holding the drum. The brake is the lower part of *P*. The space between the outer and inner spindles is filled with oil and needs no further lubrication. There is no vibration of either the apparatus or the floor.

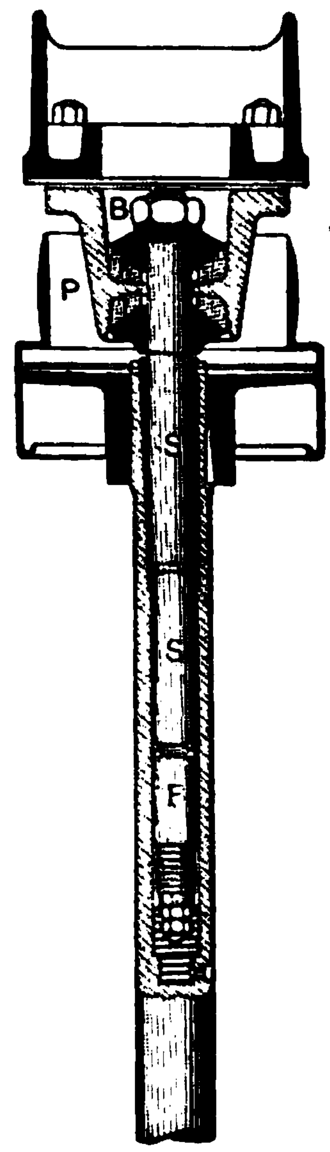

FIG. 157.

There are numerous ways in which this type of centrifugals may be suspended. The HEPWORTH type differs from the foregoing by a bearing for the lower end of the spindle connected with the outer casing. All these centrifugals are very simple in construction, and, needing no foundation, may be placed where other types could not be. The argument advanced by FESCA,[1] that they are not balanced, does not hold good, as shown by the above explanation. This authority also claimed that they were slow to set spinning and were not suited to powerful brakes. Whatever may be the reason, the fact remains that the suspended centrifugals have been used comparatively little in European beet-sugar factories.

Under-driven centrifugals.—The under-driven centrifugals are generally placed in front of a horizontal transmission, consisting of two pulleys, one fixed and

[1] S. I., **32**, 385, 1888.

the other loose, over which runs the driving belt. This belt should be properly stretched, so that the greatest efficiency may be attained; but this must not be pushed to an excess, or the advantages obtained will not compensate for the wear on the moving parts, and, furthermore, an unnecessary oscillation of the drum results.

The views of experts respecting the centrifugal belting are most varied. For example, TOBELL[1] recommends that these belts have their smooth side turned on the pulleys,—in fact, that the pulleys themselves be very smooth. The best results appear to be obtained with comparatively narrow belts. It is claimed that by this means the slip is lessened. Satisfactory results[2] have been realized by placing the pulleys commanding the centrifugal at about the same elevation as the spring bearing, so that the line of application of the force and the point of friction of the axis in the bearing are upon about the same horizontal plane. The vibrations and shock produced when the machine is started are directly transmitted to the bearing, without influencing the drum, even when revolving at a considerable velocity.

In the German type of under-driven centrifugals (Fig. 158) as made by the Brunswick Works, by means of a lever, *a*, and the

FIG. 158.—Brunswick Under-driven Centrifugal.

fork, *h*, combined with the fixed and loose pulleys, the gearing is kept under control. When it becomes necessary, owing to an abnormal stretching of the belt, *c*, the tension may be increased by means of *i*. In this centrifugal the axis is kept vertical and is balanced by the bolts, *g*. The brake is indicated at *f*.

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[1] Oe.-U. Z., **21**, 453, 1892; 457, 1892. [2] D. Z. I., **26**, 1549, 1901.

Electric driving.—Belt driving offers numerous disadvantages. It is responsible for certain accidents arising from the difficulties in handling the belting, so as to start the spinning at once. MUELLER's[1] experiments show that the loss of velocity is between 1.5 and 4.5 per cent when one or two properly stretched belts are used. Under certain conditions these losses are even greater. The conclusion is that the efficiency of centrifugals varies with circumstances, depending upon the tension or stretching of the belting; furthermore, the cost of maintenance, which is frequently great, must be considered. Do what one may, there is always a slip when passing from the fixed to the loose pulleys or friction cones.

DÜFFNER[2] claims that there is every advantage in having a simple motor for a series of centrifugals, rather than an electromotor for each centrifugal. In special cases, however, the latter system is essential. It may be admitted in general that there are greater advantages in having special motors for small centrifugals rather than for large ones, as the starting of the apparatus requires the maximum expenditure of force; too great a power is needed for a large centrifugal. This force is proportional to the square of the radius of the centrifugal drum. When several centrifugals are working together the starting of one of the series is helped by the others, and the passage from rest to motion is accomplished under satisfactory conditions. The first cost of a series of centrifugals is comparatively much less than for a single apparatus.

The weight of opinion at present seems to be to give a special electromotor to each centrifugal. Most of the recent investigations show that there are very important advantages in using motors with polyphased currents, although no argument can be advanced against the continuous current. There can be no doubt but that it is far easier to produce high voltage in the polyphased than in continuous currents. As the work wasted through useless resistance of the lime and the motor is inversely proportionate to the voltage, the possible advantage of the polyphased current begins already to be evident.

The sparks when they exist in the polyphased currents with carbons are far less objectionable than in the continuous-current mode. Furthermore, one of the great sources of difficulty with the continuous-current motor is that the rheostat is an essential adjunct for the continuous regulating of the velocity, which depends

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[1] B. Z., 14, 151, 1889.

[2] C., 9, 899, 1901.

upon the central motive power. Experience shows that polyphased currents under like conditions retain their velocity, while with continuous currents the number of revolutions varies with the steam motor, and, furthermore, their regulation demands constant care. These currents will apparently sustain very much greater variation in power consumption than continuous currents, and they also permit the recovery of the moment of energy accumulated in the basket when brought to rest. This is an item of no small importance, and may reach considerable proportions in the case of large centrifugals. A certain proportion of the energy otherwise absorbed by the brake may be recovered by successively connecting the motor of the centrifugal with alternators in which the frequency is less than in the motor proper. With these combinations the other centrifugals of the series may be set in motion. According to BRUNSWICK,[1] one may thus recover from a given type of centrifugal 36,000 kilogrammeters of a possible total of the 75,000 accumulated in the rotating drum at the time the brakes were applied.

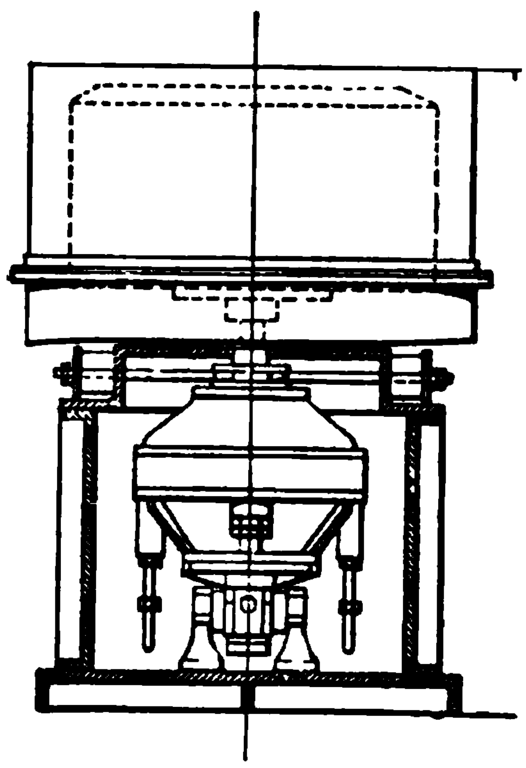

FIG. 159.—Electrical Underdriven Centrifugal.

To prevent mistakes when the brake is applied its lever is frequently used as a commutator, under which conditions it is impossible to put it in action without ungearing. In Fig. 159 is shown the arrangement for electrical driving for a FESCA motor. On the other hand, Fig. 160 shows a type of German electrical driving as applied to the WESTON centrifugal. The ALLGEMEINE-ELEKTRIZITÄTS-GESELLSCHAFT,[2] of Berlin, attaches the motor directly to the spindle of the suspended centrifugal, while the "stator" is also connected with

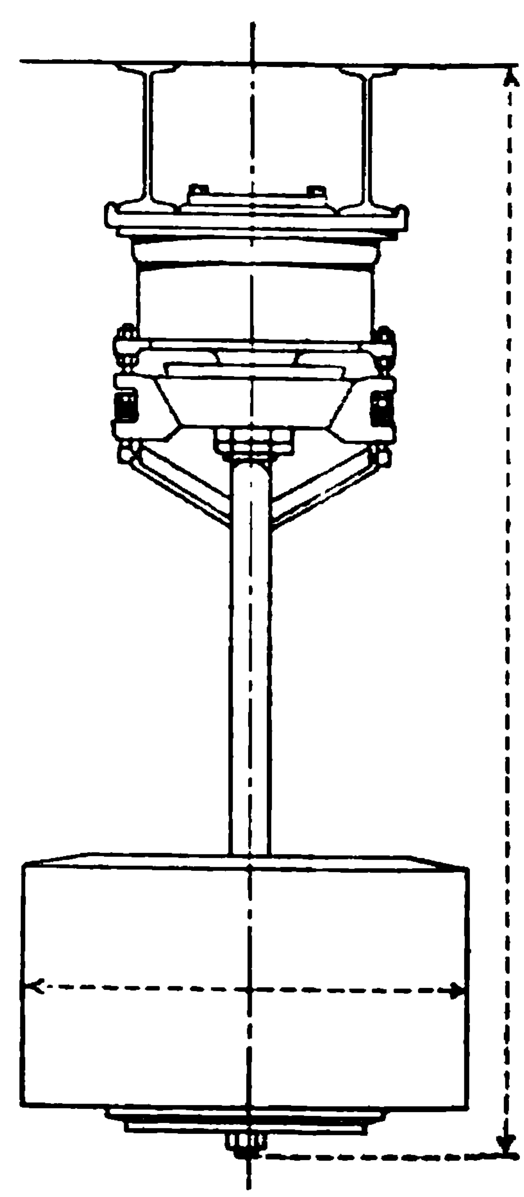

FIG. 160.—Electrical Topdriven Centrifugal.

[1] Bull. Synd., 32, 688, 1900. [2] Z., 54, 112, 1904.

the same axis by the means of rings in which the spindle revolves. Under these conditions the motor and the stator in the electrically driven centrifugals may follow the swinging motion of the axis. In Fig. 161 is shown a French triphased electrical current centrifugal. The revolving drum is 1.250 m. in diameter and 0.4 m. in height. It is wedged on the vertical spindle. The lower pivot rests upon a bearing surrounded by a suitable protecting box. A special lever permits a compensation in case of wear, and a collar placed at the bottom of this spindle assures its vertical position. On the spindle, underneath the drum, is attached the electrical motor, worked by a three-phase current having a velocity of 900 revolutions per minute.

Fig. 161.—Triphased Electrical Under-driven Centrifugal.

The stopping and starting of this motor is effected by a tripolar interrupter, the working of which is combined with the brake. The motor is enclosed in a sheet-iron mantle, which may be readily taken apart in case of needed repairs. These centrifugals work with regularity and are easily run. The Cail centrifugal has of late years undergone several modifications that electrical attachments might be used. The spindle has been lengthened, and the motor is a continuous current consuming 135 amperes at 106 to 110 volts for starting, and only 18 amperes when in full activity. These centrifugals make 1100 to 1220 revolutions. The brake and the commutator are attached so as to prevent mistakes. A rheostat is used in connection with this type.

Other motors.—Direct driving of centrifugals has been studied for many years, either ordinary engines or special devices being used. Among the applications of this kind may be mentioned the Brotherhood [1] direct steam-engine driving. One difficulty which arises is the impossibility of having steam that is constant in pressure, etc. The Buffaud direct upper-driving centrifugal has been quite extensively used in France. Numerous experiments have been made in applying hydraulic power to centrifugals, and the Pelton and other devices of the same kind have had numerous applications.

[1] S. I., 8, 506, 1874.

Centrifugals with turbines offer many advantages, as their foundations and installation are very simple and no account need be taken of the space needed for transmission. With these appliances a given velocity is not exceeded, this velocity depending upon the water pressure, which remains nearly constant. An objectionable feature is that they must be handled by regular rule and can not be forced in case of an emergency, as, for instance, if the swing-out operation should offer exceptional difficulties. Electrical motors, all facts considered, comply with all the requisite conditions and may be forced for a certain period.

The hydraulic motors permit the starting of a centrifugal without sudden shock. WATSON and LAIDLAW [1] claim that they absorb less force than other centrifugals of the same size—3.58 H.P., as compared with 4.85 H.P. for belt driving and 5.91 H.P. in case of electrical driving. These centrifugals have exceptional advantages in case there is ample water power at one's disposal.

FREITAG'S [2] original idea is interesting, according to which the motive power of centrifugals can be obtained by the swing-outs of the centrifugal itself, which product is forced by a pump under a pressure of 10 atmospheres and sent through a series of injectors in the interior of a special turbine. That the swing-outs may retain the desired fluidity a slight steam injection is necessary on the exterior of the drum. The drum of the centrifugal has a conical sleeve that turns with it, and guides the swing-out into the receiving gutter. Under these circumstances the efficiency of the apparatus becomes greater. The special advantage of this centrifugal is that it may be rapidly put into motion, which is one of the essential conditions in order that the massecuite be homogeneously distributed in the drum of the apparatus.

Motor.—The force absorbed by centrifugals when in full activity varies from 2 to 6 and even 8 H.P., depending upon the weight of the load. When centrifugals are driven by belts the central motor should be equal to the work to be done, and have a heavy fly wheel to regulate their running. When these are suddenly started they may require as much force as is needed for five centrifugals during their full spinning, and this has a tendency to influence the running of the other apparatus.

VIVIEN [3] recommends that two valves be placed on the motors

[1] WATSON and LAIDLAW, Centrifugal Machines, 24, 1903.

[2] C., 9, 47, 1900.

[3] S. I., 8, 125, 1873.

of centrifugals, one inside and the other outside the factory, so that the centrifugals may be stopped from a distance in an emergency.

Emptying of centrifugals.—Most of the top-driven centrifugals used for beet sugar are emptied from the top, that is to say, by means of a wooden or metal ladle or shovel. The sugar is emptied into a hopper attached to a bag, into boxes, or into a mechanical carrier. At Meaux (France) aluminium shovels are used, and the mechanical labor thus saved is estimated at 16,000 kilogrammeters daily for each workman. This work is very fatiguing and could not be accomplished by such means with the large centrifugals now used. Every effort has been made to render the work easy, and bottom emptying has this object in view.

The first European centrifugal of this kind was introduced by Fesca [1] in 1875. The drawing (Fig. 162) shows the arrangement as seen from the bottom, the openings, three in number, being represented by *f*. They may be closed by the parts *d*, which revolve around the pivot of the centrifugal, their movement being limited by the clicks, *e*, and the grooves, *v* and *w*. There is a hopper for each opening, *f*. The sugar falls into the carrier, and before the drum of the apparatus is filled with the load the openings are closed.

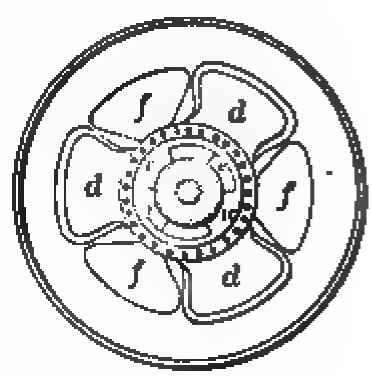

Fig. 162.—Bottom Emptying.

In Fig. 163 is shown the arrangement for bottom opening as made by the Brunswick Works, Germany. In this case two flap valves, placed at the bottom of the centrifugal, open successively over a hopper, *b*, communicating with the carrier. When the spindle bearing is worn the pivot may be lowered by means of a lever, *l*. In the upper part of the casing there is a hole through which a peg may be placed, holding the drum in position so that its bottom opening will correspond exactly to *b*. Precaution must be taken to remove

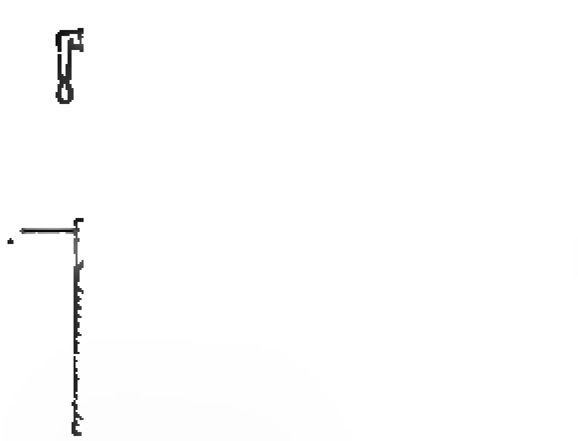
Fig. 163.—Bottom Flap Valve Emptying.

[1] Z., 39, 190, 1889.

the peg before the spinning is resumed, as the drum or the outer casing could be deteriorated. ROESMER[1] proposes to overcome this difficulty by making the end of the peg of some soft metal which will break under abnormal strain and may be readily replaced.

Periodic centrifugals.—Several times attention has been called to the power needed to set a centrifugal spinning and the energy lost when bringing it to rest. Efforts have been made to partly overcome the losses of power by filling and emptying during working. This may be accomplished in two ways, either by periodic or by continuous centrifugals. In the HAMPL[2] apparatus the drum is a truncated cone, the larger diameter being at the movable bottom, and may be removed when the swing-out operation is finished. The sugar is projected downward into a hopper connecting with the carrier. The bottom is then replaced and another load is introduced without the spinning ceasing or changing its velocity at all. The bottom is lowered and adjusted by means of levers. There are numerous types of these periodic centrifugals, but few of them have been introduced into practice.

Continuous centrifugals.—The first attempts at continuous centrifugals were those of SEYRIG[3] in 1850. While the method did not meet with much favor, numerous inventions having the same object in view have since been made, but the problem has not yet been solved. The SZCZENIOVSKI and PIONTKOVSKI[4], continuous centrifugal is the only one that has been used to any extent (Fig. 164). It consists of a perforated sheet-iron conical-shaped drum, *cc'*, covered with a metal filtering sheet. The masse-cuite is emptied into it by means of an endless screw, and the feeding pipe, *a*, entering the drum through the bottom opening, *b*. The centrifugal force compels the mass to rise along the sides, *cc'*. A distributing plate, *e*, equalizes the product, forming a uniform thickness of 2 to 5 cm. During its upward movement the molasses are more and more separated, and are projected against the outer casing, *K*, running out through the openings, *h* and *i*.

The sugar separated gets nearer and nearer the upper edge of the drum, in fact it has a tendency to fly off too rapidly. To prevent this there is an upper ring, *d*, which revolves at the same velocity as the drum, but is independent of it, and which is the regulator of

[1] D. Z. I., 25, 852, 1900. [3] Z., 1, 58 and 395, 1851.
[2] Z., 53, 427, 1903. [4] S. I., 37, 547, 1891; 40, 669, 1892; 41, 565, 1893.

the apparatus. The relative position of the ring and the drum is made to vary by means of a conical gearing, *rs*, that raises the spindle. The cured sugar is projected into a trough, *f*, in which a carrier revolves. This centrifugal is driven by a pulley, *w*, and can be readily lubricated. The drum of this apparatus originally had a velocity of 410 revolutions per minute, but this was increased to

FIG. 164.—SZCZENIOVSKI and PIONTKOVSKI Continuous Centrifugal.

470. It is claimed that a machine of this kind has the same practical efficiency as seven ordinary centrifugals.

Practical considerations.—Raw sugar is obtained by the simple swing-out of the massecuite. The greater the charge the larger will be the quantity of raw sugar obtained during a given period of working, as considerable time is always lost in starting and stopping the apparatus. According to TOBELL,[1] the time that the centrifuging lasts decreases proportionally with small loads;

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[1] Oe.-U. Z., 21, 778, 1892.

but, on the other hand, the time lost in starting and stopping is proportionally greater in small than in large appliances; so, upon general principles, it may be said that the efficiency of a large centrifugal is greater than that of a small apparatus. Centrifugal of 750 mm. diameter have a velocity of 1000 to 1200 revolutions per minute and receive a load of 60 to 80 kilos of massecuite. The large types, having diameters of 1.100 to 1.250 meters and making 700 to 1000 revolutions per minute, receive loads of 150 to 500 kilos of massecuite.

The practical handling of a centrifugal is about as follows: The starting is comparatively slow; when the casing has an upper cover it is put in position; steam is injected into the drum and when the exterior casing is warm and there is no longer any danger of cooling off the mass against the sides the cover is removed. The speed being very low during the filling from suspended cars or hoppers the load is well distributed over the drum. For other massecuite carriers the centrifugal must be brought to rest while filling up to a certain height, after which the apparatus is set spinning and the mass rises along the sides of the filtering surface. Efforts should be made to have the thickness of this layer very regular, and this will not be the case if the drum is too high, for then irregularities always exist, and the product being thinnest on top, the lower layer is not as well cured as the upper. This condition is plainly shown by the difference of color in the final sugar at the top and bottom of the drum.

In some portions of the product the syrup continues to adhere to the surface of the crystals. The slower the starting the less tendency there will be for the sugar crystals to pack against one another and close some of the perforations of the filtering sheet, which always results in a reduced efficiency. As the operation progresses the massecuite changes in color, becoming brighter and brighter as the after-products are more thoroughly separated. In most European beet-sugar factories, where the raw sugar standard is about 88°, the swing-out continues until a standard tone of color is obtained. With a certain amount of experience this determination is not difficult. In large centrifugals the inside and outside intensity of color is very different. Upon general principles, it may be said that the curing takes from 2 to 10 minutes, depending upon the size of the apparatus and the size of the grain. In that time nearly all the syrup has been separated from the crystals, and the centrifuging is finished when no more of the swing-out passes the filtering sheet.

If a massecuite contains considerable mother liquor it may appear very fluid and yet in reality be viscous, in which case the syrup adheres to the crystals very tenaciously. Spraying with water is then necessary, but should be done very sparingly. Final steam spraying gives the ideal color for 88° sugar. The application of the brake should be gradual, for reasons explained in the foregoing. With certain massecuites the sugar separated and adhering to the filtering sheet falls of itself as soon as the spinning ceases while in other cases it must be detached with shovels or ladles In order that the sugar of the load may have a uniform color it is generally mixed in the drum before being removed. The bottom emptying valves are then opened and the product falls into the sugar carrier, while in the case of overhead driving it is shovelled out. For this work only very robust men should be employed. A centrifugal is a very dangerous apparatus in careless hands. It is most important that it should be kept very clean, otherwise serious sugar losses result, and all the moving parts should be well lubricated.

Perturbations.—When the first-grade massecuite has been properly grained and worked no difficulty can possibly arise in the separation of the crystals and the after-products. The swing-out is then one of the simplest and easiest operations of all the manipulations in extracting sugar from the beet. With a massecuite of satisfactory quality the after-product is separated from the crystals before the centrifugal has reached its maximum velocity. Evidently less syrup adheres to the upper layer of the crystals than to the portions coming directly in contact with the perforated metallic covering on the drum; however, the difference is not very great, and during the emptying and carrying the sugar is sufficiently mixed.

When the massecuite swing-out is not readily accomplished the spinning at a maximum velocity should continue for a longer period. Even then a considerable amount of the after-product still adheres to the sugar crystals, a condition which it is difficult to overcome in the centrifugal, at least without considerable loss It is better to prevent than subsequently correct such irregularities. The faulty swing-out is generally due to false grain, which forms when the crystallization process has been badly managed. There are, however, other causes of this difficulty, among which may be mentioned the viscosity and the froth which may form during the agitation of the mass.

False grain.—It does not necessarily follow that because false grain has been produced during the strike the curing will be difficult. If the false grain has had time to grow to a reasonable size the swing-out offers no difficulty; the reverse is the case if the false grain has been produced toward the end of the graining in pan or during cooling.

False grain under the influence of the centrifugal motion will deposit upon the surface of the large crystals. From the massecuites that are difficult to handle in the centrifugal there is deposited a layer of sugar, more or less freed of its adhering syrup, then a layer of false grain, the particles of which stick together, and on the outside molasses which have been unable to penetrate the mass. When one has to contend with these inferior massecuites the best thing to do is to dissolve the false grain in the crystallizors, or the mixers, by adding a highly heated after-product, or to thoroughly dilute them. If this is done with care there need be no apprehension that too much sugar will be dissolved at the expense of the large crystals.

The facility of working the grained product in the centrifugal depends upon the quantity of false grain present and its degree of fineness. All massecuites contain a certain amount of these small crystals, which fact is made evident by examining the product under a microscope. The curing of massecuites of this kind always occasions considerable loss of time, and certain precautions should be taken, such as submitting the contents of a crystallizator to a trial in a centrifugal several hours before the time for curing. If found difficult to handle it should be worked on at once. In this way the regular running of the factory will not be disarranged.

The only way to overcome this difficulty, when handling poor massecuites, is to use live steam in the drums of the centrifugals, which will necessarily dissolve a certain amount of sugar through dilution and reheating of the mother liquor. Instead of introducing live steam into the drum of the centrifugals it is preferable to use it between the drum and the metallic cloth covering; the steam then has a slow and more regular action, under which circumstances too many of the larger sugar crystals are not dissolved. By this method of working the loss of sugar is greater than it is with kneading appliances or in the crystallizors.

Viscosity.—The viscosity may arise from many causes, such as excessive tightening during graining or too sudden a cooling of the product in the crystallizators. MALANDER points out that the

general aspect of the swing-outs gives important indications as to the difficulties that must be overcome during curing. If the load of massecuite introduced into the centrifugal is too hot the syrup adhering to the crystals may at first be readily separated; but as the curing continues the crystals may pack on one another. The cold air from the room passes through the mass of sugar already separated, drying it and resulting in a great adherence of the after-product to the crystals.

Care should always be taken to prevent the cooling of the crystallized mass below 50° C., for the reason that at a low temperature the viscosity of the saturated solutions, and more of the supersaturated ones, will increase considerably. It is for this reason that cooling during the interval of the passage from the crystallizators to the centrifugals is always followed by complications during the swing-out, and should, therefore, be avoided as far as possible. It is difficult to complete a sugar campaign without some trouble with the massecuite in the crystallizators. When possible the product is diluted and the viscous condition is thus obviated; but when the difficulty is due to viscosity alone heating helps to overcome the difficulty. If this cannot be done in the crystallizators a certain quantity of diluted hot after-product may be added, thus lowering the degree of supersaturation.

Frothing.—Frothing occurs generally when the massecuite only half fills the mixing refrigerator. It is evident that frothy massecuites are difficult to swing out in centrifugals, as the frothy syrup attaches itself to the sugar and forms a viscous pellicle on its surface which the centrifugal force cannot remove.

Swinging.—However carefully a load in the centrifugal may be handled there is always some swinging occasioned by the fact that a greater volume of the product being worked collects at one spot, thus changing the centre of gravity of the drum during its spinning. As allowance is made for this by the use of elastic buffers connected with the spindle, the swinging will increase as the centrifuging continues and will reach a point when even the outside casing is knocked by the revolving drum, causing danger of an accident. Of late years this difficulty is not so great as formerly, as the modern centrifugals are more strongly built and have outer casings of steel.

When the indications are that the product will be difficult to handle in the centrifugal, steps should be taken to prevent accidents. The attendant keeps the centrifugal under control until it reaches

the normal number of revolutions by maintaining it with a wet cloth placed on its upper border, thus preventing the shock of the drum against the outer casing. The FESCA mode for preventing the swinging is interesting (Fig. 165). The bottom, *b*, is shaped like a hood, *d*, and is attached to the spindle, *e*, by a disk, *g*, with conical sides, *i*, the whole being tightened by means of the nut, *n*. The regulator consists of a series of washers, *l*, separated by the plates, *k*, which, owing to the inertia, tend to place themselves in a position opposite to that of the spindle's slant; and the displacement of the centre of gravity then no longer exerts its influence. The nut, *m*, holds the rings, *l*, in place.

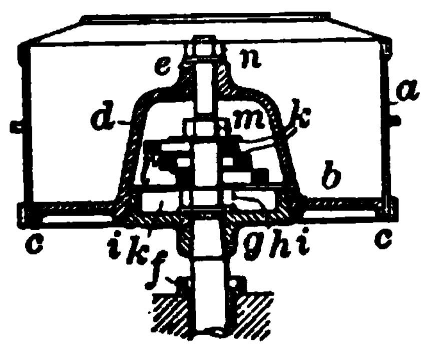

FIG. 165.—Swinging Regulator.

Explosions of centrifugals.—When centrifugals were first introduced into sugar factories fatal accidents were of frequent occurrence. They are now the exception, but are still possible from the wearing away of the sheet iron of the drums, or from too high speed due to the motor being out of order. Excessive loading is difficult to prevent, and yet it may cause the death of the person in charge. MUELLER[1] points out that the drums may last 30 years or they may be entirely worn out after four campaigns. The rivets at the bottom of the drum soon wear out, and the different parts should be repeatedly inspected.

SCHNIRCH[2] points out that in centrifugals used in a refinery the thickness of the side of the drum was lessened 13.59 per cent after one year, it being supposed that its original thickness was 5.74 mm. This same authority maintains that rust is largely responsible for these changes. EGGERS[3] recommends, in case the perforated sheet iron of the drum becomes big-bellied, forcing a hot ring, having a section of 16×40 mm., over its outer surface, which will render it more resistant. The outside casing of the centrifugal may also become corroded, but this is of very little importance.

Velocity of centrifugal.—The safety in handling a centrifugal depends also upon the velocity at which it is spinning. BRAUN has constructed a very simple contrivance (Fig. 166) for determining the velocity of a centrifugal, which consists of an inverted glass bulb filled with glycerin. If the bulb receives a rotary motion the

[1] B. Z., 14, 155, 1889. [2] B. Z., 13, 87, 1888. [3] Z., 39, 53, 1889.

meniscus will assume an elongated form, the apex of which will vary in relation with the centrifugal velocity. A graduated scale on the outside of the glass, determined by experiments, gives exactly the number of revolutions made.

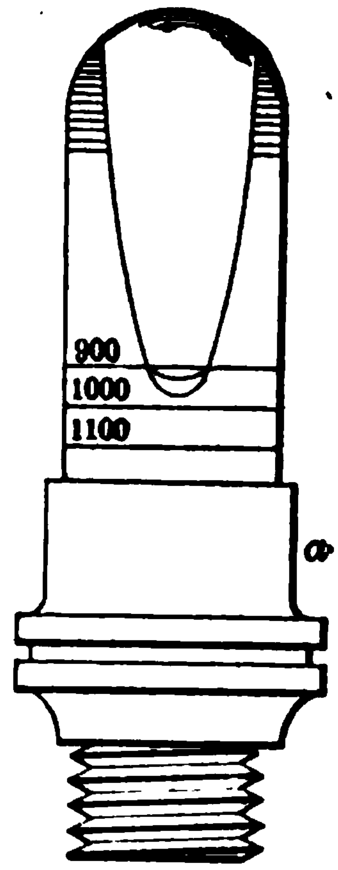

Fig. 166.
Velocity Indicator.

By altering the conditions of the load and the velocity of centrifugals the danger of accident, as previously pointed out, is very much lessened. According to Tobell,[1] when the velocity is reduced from 1000 to 900 the efficiency is lessened by 5 per cent, but the safety coefficient is increased by about 23.5 per cent. Reducing the load does not bring about the same results. By decreasing the load 10 per cent the efficiency falls 5 per cent, but the safety coefficient does not increase by even 10 per cent.

[1] Oe.-U. Z., **21**, 780, 1892.

CHAPTER IV.

TRANSPORTATION AND STORAGE.

THE KREISZ carrier, spiral carriers, horizontal belting, vertical chain-pocket elevators, linen oblique-pocket elevators, boxes, and small cars are used for the transportation of sugar.

The Kreisz carrier (Fig. 167) consists of a suspended trough, *a*, supported by slanting and flexible blades, *b*, which receives a series of shocks in the direction of its length by means of a connecting rod, *c*, set in motion through the pulley, *d*, and the belt, *e*. As a

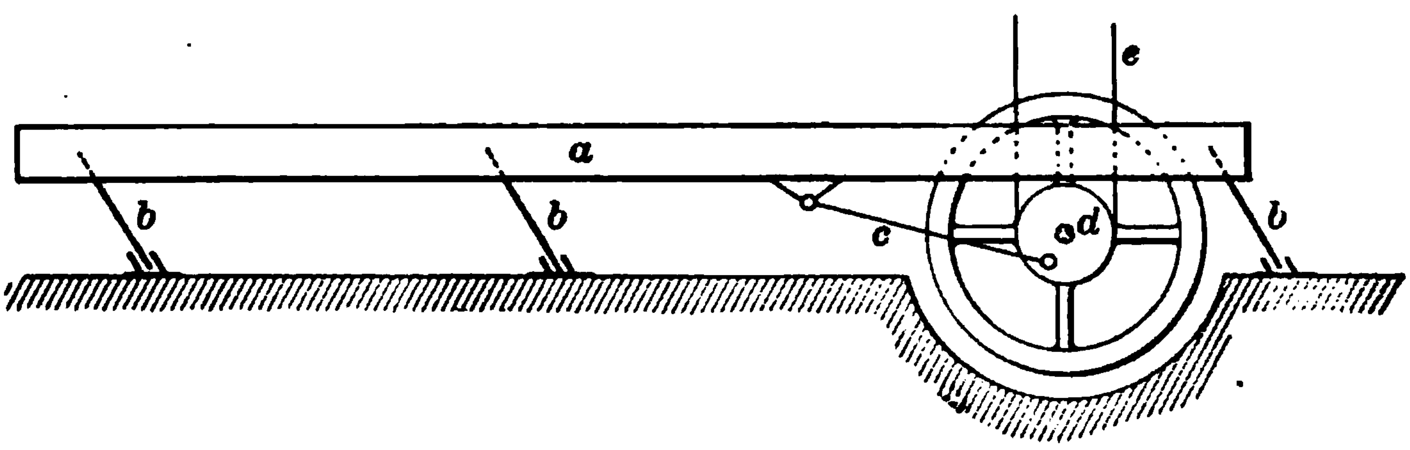

FIG. 167.—Schema of KREISZ Sugar Carrier.

general thing, the number of shocks received by this carrier is from 200 to 300 per minute, and at each vibration given to the gutter the sugar moves forward. Under certain conditions, as when the sugar is very viscous and has been difficult to handle in the centrifugals, the transportation may be troublesome. The appliance under consideration is very widely used, for the reason that the sugar crystals are not broken as in spiral carriers. The latter consist of a spiral revolving in a sheet-iron trough, which frequently has its inner surface enamelled. This reduces the friction against the sides, there is less tendency to stick in the case of viscous products, and the apparatus is readily kept clean.

Belt carriers may be said to be unsuited for sticky sugars, and their use is mainly confined to the transportation of white sugar. Generally the sugar must be raised to the sifter, and for this pur-

pose pockets mounted upon EWART chains are used. While these are of satisfactory efficiency they crush the sugar between their links. The dust created by the falling down of the sugar sticks between the links of the chain causing it to stretch and lessening its flexibility, so that there is danger of rupture. Hence it should be cleaned as often as possible.

To prevent the sugar dust from escaping this elevator is enclosed with boards. In certain beet-sugar factories bag cloth is used for covering, which retains the dust and at the same time permits cool air to enter. The oblique linen pocket elevators are used mainly for white sugar. These lifts or elevators should be kept running and fed with regularity. Their efficiency must under all circumstances be known in advance, that all the centrifugals be not emptied at the same time.

Sifting.—Sugars upon leaving the centrifugals are not homogeneous in appearance. In most cases they contain lumps of sugar, etc., which may be separated by sifting, provided they are sufficiently large to be retained by the sieve. When they have been removed they may be remelted and added to the juice in some phase of its working. If allowed to remain they would very much depreciate the market value of the product from the refiners' standpoint.

The STOLC-KABA (Fig. 168) sifter and classer is fed by a large spiral elevator, *A*, that empties the sugar into the hopper, *B*, from which it falls into a small distributing spiral, *a*. The first mixing begins in the spiral, *A*. The sifter, *C*, consists of a truncated hexagonal pyramid around which a steel wire is wound. The sugar enters this sifter by the smaller end, and, owing to the slant and direction of the generatrix, travels the entire length of the apparatus distributing the sifted sugar into two hoppers, from which it falls into small cars. At the end of the sieve are slanting laths, *D*, which force all lumps, etc., to escape from the apparatus into the disintegrator, *E*.

The MAY [1] sifter also consists of a truncated pyramid made up of metallic network. In the lower portion of the rotating sieve are two rollers intended to crush the lumps, which then again fall into the sieve. The spacing of these rollers is regulated by springs which act when the pressure reaches a given limit.

When high-grade sugars are worked, they are very readily sifted

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[1] B. Z., 19, 486, 1895; 2, 20, 390, 1896.

through any system of sieves. On the other hand, if the sugars are moist and only of 88° polarization, owing to their viscosity, certain difficulties arise. For these sugars the joggling sieves, and those on the drums made of wires wound around, their intersections being kept open by the use of brushes or some other device, give the best results. As the viscosity of sugars increases with cooling, the sieve should be arranged so as not to permit cold air to be brought in contact with the product during the bolting

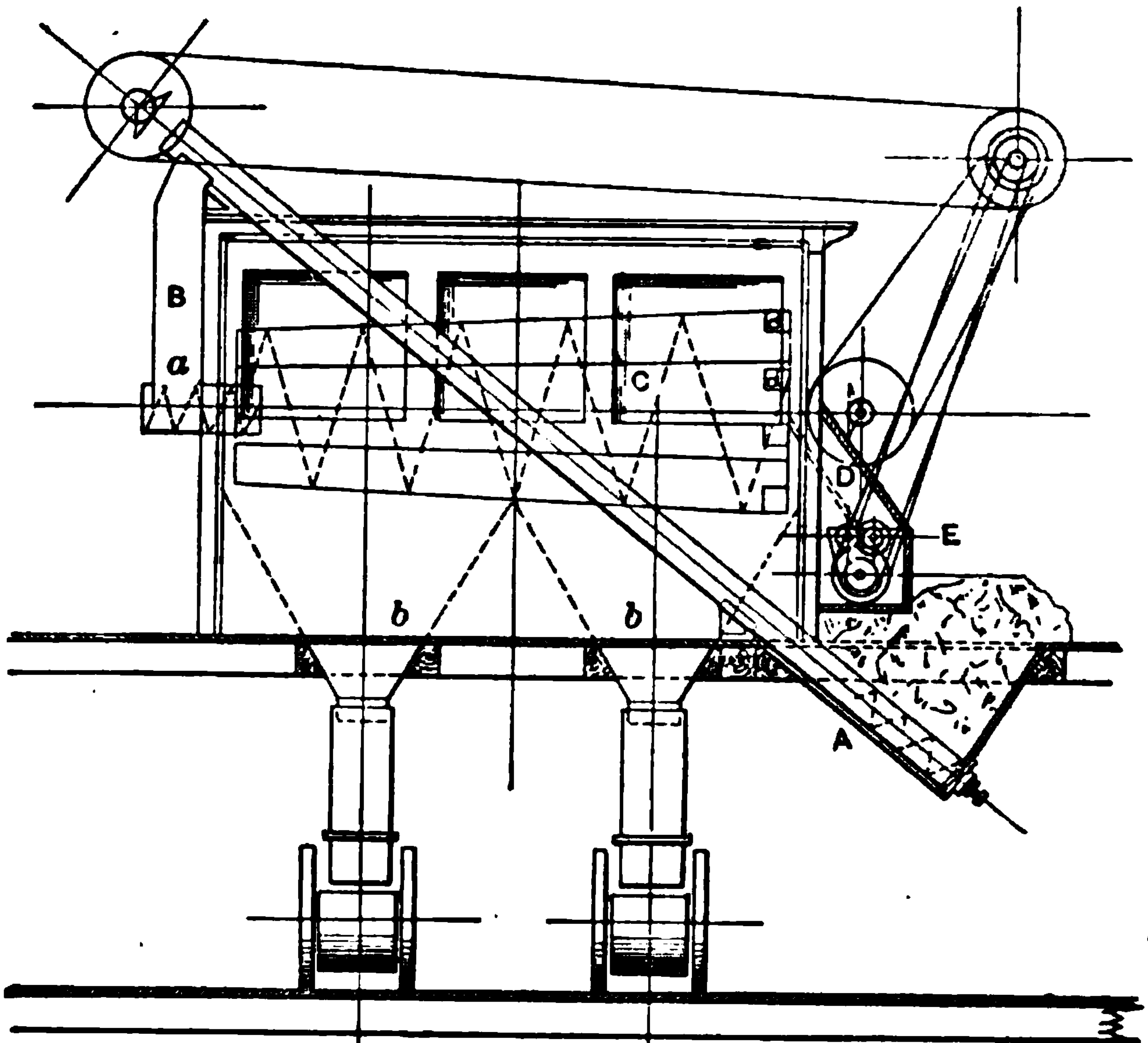

FIG. 168.—STOLC-KABA Sifter.

process. The size of the mesh of the metallic bolting cloth depends upon the nature of the sugar to be sifted. In small beet-sugar factories the sifting is done by simply shovelling the sugar on to a slanting sieve, but this demands considerable labor.

Before the sugar is put into bags it should be thoroughly mixed, because the product obtained from different strikes, even in the same factory, may have a very dissimilar quality and aspect. High buildings are essential for these varied sugar manipulations, for then the product may fall from floor to floor through special openings adapted to the purpose. The mixing of sugars of the several strikes is done as the descent progresses, and one is able under these conditions to obtain any shade of color that the trade

may demand. During the fall, the sugar crystals should be kept well apart, so that they may be thoroughly cooled before the sacking commences. When handling warm sugar, cold currents of air should be avoided, as these would cause the surface of the sugar to cake.

Warehouses.—After its final treatment the sugar is carried to the warehouse either in bags or loose. Under no circumstances should sugar be put in warehouses while still hot, for the temperature would then still further rise in the mass, and as a consequence, at the centres where this heat is produced, the color of the sugar becomes darker, its alkalinity drops, and a certain amount of sugar is inverted. These phenomena correspond to special oxidations, resulting in the formation of certain non-sugar substances. When the sugar is still hot after the sifting, it should be collected in small piles so that it may cool, and then only be placed in bags.

The GREDINGER[1] appliance, for the preliminary cooling of sugars before being stored, consists of a vertical cylinder with a revolving central axis, to which are attached arms, forcing the sugar to fall vertically on a series of conical shelves; cold air is forced in by a ventilator from the bottom. The sugar, when reaching the extreme lower level, falls upon an oscillating sieve.

In factories that do not have the advantage of upper floors, all the mixing must be done by hand. The product is emptied from the cars onto the floor in piles and is mixed with shovels. This necessarily means a considerable increase in the cost of working, and demands great cleanliness during each stage of the manipulation, or serious sugar losses may follow. The men work barefooted, so as not to crush the sugar. The shovels used should be scraped and kept clean, which may be thoroughly effected by dipping them into the hot juices of the first carbonating tanks.

Numerous devices have been proposed for putting the sugar in bags, and among them mention may be made of that of KUENNETH and KNOECHEL,[2] consisting of a hopper, which contains a flap valve working on a pivot. By pushing a lever, the exit flow of sugar into the bags is regulated. One man is amply sufficient for the work. In most factories there is simply a hole in the floor corresponding to the top of a hopper, and at the other end is a sack cloth reaching within about one meter of the ground. When the bag is full, the cloth is simply pressed and the feed from the hopper

[1] B. Z., 23, 97, 1898. [2] D. Z. I., 27, 1813, 1902.

ceases. To keep the hopper constantly filled demands several hands on the upper floor and several below, at least twelve persons being needed to carry on the work rapidly. Among these hands are two women, who constantly sew the bags, and two men for the weighing. It is possible, under these conditions, to fill 150 bags per hour.

The bags, subsequent to their weighing, are carried on barrows to the adjoining room, and are there stood side by side and sewed up, after which they are placed in the storeroom. In case this is on another floor, the bags are pushed down boards placed at an angle of 45°. After a time the boards will have a high polish, and the sliding will be correspondingly easier, unless the bags are wet, in which case a small quantity of sawdust sprinkled over the surface will help to overcome the difficulty. On the other hand, if the sugar has hardened in the bags, the shock is so great, when the destination is reached, that the sack breaks open. A small quantity of molasses placed on the surface of the plank acts as an arrestor during the sliding. Care should in all cases be taken to get rid of all the old bags. After they have been returned from the refinery they are washed, mended, and put to one side in bundles of twenty-four, the twenty-fifth bag being used as an outer casing for the others. Sometimes there are automatic counters on the sliding boards, consisting of a small clamp projecting on one side, against which the bag knocks during its descent. This arrangement is objectionable in that it records the passage of any and every thing sliding down, and therefore it is better to count the bags in the usual way.

It is desirable that, as far as possible, the walls of the warehouses should not be subjected to excessive pressure. Their thickness should depend upon the weight to be supported, and they should be properly braced. When sugar is stored in bags, special precautions should be taken to prevent them from touching the walls, and to pile them up as is done with bricks, that is to say, alternately in longitudinal lines and lengthwise, so that the pile will form a closed mass, and no extensive tumbling will take place when some of the bags are removed.

Sugar warehouses should be cool and dry. In all cases care should be taken not to store the product over a hot room, or where it may come in contact with hot, moist air. In overheated rooms the sugar would dry and lose weight, and, furthermore, it would be more difficult to refine, as the syrup upon the crystals would become

more viscous. In damp rooms, on the contrary, sugar will draw upon the water, and become so moist that the resulting syrup may run from the crystals and micro-organisms may develop, resulting in inversion. In a cool and dry warehouse no changes of this kind take place if the sugars have been properly handled in the centrifugals, even when they have a polarization of only 88°, as the syrup is viscous at low temperatures, owing to the supersaturation, and remains on the small crystals as a pellicle.

In some cases, as previously pointed out, the sugar is simply piled up on the floor of the warehouse, but even then it should be properly cooled. When this mode is adopted, the cars containing the sugar are counted, and subsequently pushed to the room where they are unloaded. Experience shows that this operation is frequently neglected, and the result is that the weight recorded is seldom exact. The weight of the sugar in a warehouse cannot be determined by measuring its volume, because the specific weight varies very much with the size of grains and crystals, and also with the nature of the raw sugar and the height of the piles. With a view to save labor, the sugar, being taken to warehouses, is emptied into the cars from centrifugals, or falls through suitable holes into the gutters of the carriers.

The warehouses should always be dry and have constant temperature, and the walls should have an interior plank covering. It is admitted that one cubic meter of sugar weighs about 900 kilos, and this relation is used in calculating the strength of the girders, although it is only approximate, as there are many factors to allow for, such as the size of crystal, moisture retained by the sugar, etc.

Standard raw-beet sugar.—Raw sugar is made up of crystals and adhering syrup under very much the same condition as exists in the massecuite. The essential difference is, that there is less syrup than in the grained product, the composition of the syrup being identical in the two cases. The different polarizations of raw sugar that may be obtained from a massecuite depends upon the duration of the swing-out and the quantity of syrup still adhering to the crystal surface. Claassen says that, in a massecuite, for 100 parts of crystals there are 30 to 60 parts of syrup, depending upon the method of graining; but in the raw sugar there are only 6 to 12 parts. The average thickness of a layer of syrup upon the crystals is, for sugar of 92° polarization, 0.01 to 0.015 mm.; and for sugar of 80° polarization, about 0.015 to 0.02 mm.

The question as to whether it is more advantageous to produce

a high rather than a low testing sugar depends upon the prices in the local market. The advantages and disadvantages of working sugar of a given grade depend upon a series of factors, such as the current prices upon the market and the degree of refining yield. If one accepts the CLAASSEN calculations, there is an advantage in producing sugar with high polarization when an increase of 1° of polarization is paid with an increase of one per cent in the price. That is to say, if sugars yielding 88 per cent refined are selling at 3 cents per pound and the price rises 0.03 cents for sugar at 89°, then there is an advantage in increasing the quality to 89°. In order to produce better sugar, more centrifugals are required, and the quantity of after-products to be worked is increased, and it remains to be determined whether the installation of the sugar plant will permit this supplementary work.

The *quality* of raw sugar, that is to say, the facility with which it allows itself to be transformed into an article of consumption, does not depend upon the yield, but upon its exterior properties such as brilliant, well-formed, and regular crystals, white in color, and with an adhering syrup that is not too viscous, and that is freet as far as possible, from many small crystals. For the manufacture, of certain products, there is a demand for very large crystals. I, would be rational that all these factors should enter into the selling price of sugar upon the market. The purchase based upon the polarization and ash percentage does not correspond to the actual conditions, for the reason that the yield of refined sugar does not depend only upon the ash, but also upon the organic non-sugar, and also upon the nature of this non-sugar. But all proposals to introduce some plan giving an accurate valuation of raw sugar have failed, because the methods of analysis employed are not reliable. The consequence is that, as the examinations based upon the polarization and ash apply to the commercial requirements, they continue to be used.

Color of sugars.—A high-grade raw sugar, from which may be made an article ready for consumption, should always be obtained with superior beet juices when the operations of sugar extraction have been looked after with all the care and detail that modern science and observation prescribe. Raw sugars that were difficult to handle in the centrifugals never give satisfaction when refined. Their color does not always furnish a basis for estimating quality. Notwithstanding the fact that general preference is given to a light sugar, one should consider whether this clear color is

natural or the outcome of some chemical treatment. Furthermore, the coloration of the syrup, upon which that of the sugar depends, has far less importance than that of the crystals, and the latter are frequently found whiter in dark sugars, that is to say, in crystals that are surrounded by a dark syrup, than in brighter raw sugars. When the sugar crystals are not perfectly white, a slight yellow hue is less objectionable for refining than a gray coloration, because this yellow color may be more readily removed with boneblack, and may be hidden with marine blue, giving a pleasing and more soluble product than is possible with gray sugars.

KOHLER[1] claims that the red coloration of certain sugars is due to ferric salts. On the other hand, FRANK[2] maintains that the red coloration of certain sugars has its origin in mushrooms having spores (Saprolegniaceæ or Chytridiaceæ), the protoplasm of which when dead will contract and turn red. CLAASSEN says that the gray coloration is due to a small percentage of ferric salts in the juices, which is the outcome of poor saturation. Iron salts become dissolved and remain in the solution when the saturation is not sufficient, and lime saccharate also continues to exist in the solution. Carbonatated juices that remain acid will always contain iron, and the raw sugar extracted frequently is handled with great difficulty when a perfectly white product is desired. The presence of sulphuretted hydrogen in the saturation gases will, as a general thing, cause a gray coloration, possibly due to the formation of a small quantity of sulphid of iron, which remains dissolved in the saccharine juices.

According to HERZFELD,[3] the acid juices (acidity indicated by the phenolphtalein) will dissolve iron from the appliances in which they circulate. This iron may be for the most part precipitated by sulphuring and carbonatation, provided the alkalinity is not lowered beyond a specified limit. For the same reason, a low temperature during defecation will influence the aspect of sugar. MUNIER[4] attributes the gray coloration to the presence of sulphids, which may be formed by the presence of sulphuretted hydrogen in the carbonic acid gases, and also by the decomposition of albuminoids contained in the juice. ANDRLIK and STANEK[5] claim that the gray color of sugar is due to ulmic acid.

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[1] D. Z. I., **20**, 864, 1895.
[2] La. S. B., **20**, 65, 1891.
[3] Z., **46**, 1, 1896.
[4] D. Z. I., **20**, 1743, 1895.
[5] B. Z., **19**, 502, 1895.

Shape of crystals.—The shape and other characteristics of a sugar crystal not only depend upon the quantity, but also upon the nature of the non-sugar. The properly limed and carbonatated juices yield harder and more regular crystals than juices that have been submitted to a poor defecation. Given equal purity of the juices, the sugars obtained at the beginning of a campaign with fresh beets are always of better grain than those obtained with siloed beets at the end of the season. Certain calcic salts, mainly those that accumulate when working by the processes used in sugarateries, appear to have a special influence upon the crystallization. All sugars obtained from such juices, and especially those from after-products, are always needle-shaped and very pointed.

Alteration of sugars.—Most authorities agree that the darker portions of raw sugars are found in those centres of highest temperature where there is the least ventilation and the piles are the highest; hence the importance of thoroughly cooling the sugar before putting it into bags, and of never piling these up beyond a certain limit. THIEL[1] denies the bad influence of heat. It has been noticed that it is mainly the inner surfaces of layers of sugar that change color. When the juices have been submitted to an excessive sulphuring, it may be noticed that their light hue disappears and they become very much browner. This led to numerous discussions when the STEFFEN-DRUCKER mode of working appeared. The real cause is difficult to explain.

A good raw sugar should be possessed of certain keeping powers; this requires an alkaline sugar free from germs, which have an inverting effect upon the syrups. Raw sugars, when kept in warehouses for any length of time, undergo a retrogradation in their polarization. Much has been written on this subject. In 1880 GAYON[2] called attention to the important fact that sugars during storage lost their alkalinity, and at the same time certain reducing substances were formed. Even at that time alkalinity was thought to play a most important rôle in the question of the keeping qualities of sugar.

STROHMER'S[3] observations were upon sugars made by several processes: First, made with considerable boneblack; second, with very little boneblack; third, without boneblack, but with sulphurous acid; fourth, sugars made without either boneblack or sulphurous acid. Some of these sugars were kept in closed glass jars,

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[1] D. Z. I., 25, 387, 1900. [2] Z., 31, 227, 1880. [3] S. B., February, 1899.

and others in bags stored in wet and dry places. These experiments showed that raw alkaline sugars had the best keeping qualities. Inverted sugar appears as soon as the alkalinity decreases or disappears. The product kept in glass jars remained the longest without undergoing a change; that in bags, when kept in damp places, underwent the greatest change. In all cases, when changes do occur, they may be attributed to fermentation. It does not matter by what process the sugar is obtained if the alkalinity is equal to 0.033 per cent of lime.

The conclusion reached is, that the changes in sugars during their keeping are not due to chemical decomposition, but to the activity of vital organisms. It must not be forgotten that it does not necessarily follow that, because an excess of alkalinity exists, sugars will have keeping qualities.

Dr. von Lippmann[1] called attention to the fact that sugars are frequently kept for ten months, and that those which were found to be alkaline by the phenolphtalein test undergo no change; the contrary is the case for sugars found to be neutral or acid by this test. Otto[2] strongly urges that in beet-sugar factories the phenolphtalein test be used, as very gray sugars have frequently been obtained with juices that showed a high alkalinity when tested with rosalic acid, but not with phenolphtalein. Furthermore, he advances the theory that, when the alkalinity is very low, it has an influence on the texture, nerve, and fibre of the sugar extracted. On the other hand, Herzfeld's[3] experiments show that a high alkalinity is no indication of the keeping qualities of sugar. The sugar must be free from micro-organisms, for if they exist their ravages continue notwithstanding the alkalinity.

Koydl[4] insists upon it that neither the inverted sugar produced during keeping or the alkalinity give an exact idea of the changes that occur when sugars remain in warehouses. The first change is the inversion, and, owing to the reducing characteristic of the invert sugar, an acid is formed. This portion of the phenomenon is much more rapid with an excessive alkalinity, and in such cases the sugar decomposition is as great as when the standard alkalinity exists. On the other hand, in sugars of low alkalinity the invert sugar present undergoes very little change. Sugar decomposition, however, always increases with the period of keeping.

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[1] S. B., October, 1901.
[2] Z., **53**, 450, 1903.
[3] Z., **53**, 1223, 1903.
[4] Oe.-U. Z., **29**, 366, 1900.

JESSER[1] points out that the chemical composition of the non-sugar exerts no influence on the keeping qualities of sugar. If the changes that occur vary with the grade and nature of the product, this can alone be attributed to the action of micro-organisms. The formation of reducing substances is less when sugars are alkaline; but this alkalinity is finally neutralized if the micro-organisms are in a normal condition for development, whatever be the nature of the sugar, whether alkaline or acid. Microscopical examination is the true and only mode of ascertaining the keeping powers of sugar.

In 1898 the subject was discussed in several British journals. It was discovered that bacteria of a special kind were always found in cane sugars, and from this fact it was argued that in the air there are always germs of certain micro-organisms, which will develop an invertase that has been separated. The contamination occurs mainly during the working in centrifugals. Some years since, STROHMER[2] noticed that, in a pile of sugar, transformations were taking place which were plainly visible from the exterior appearance of the sugar. It could not be decided by that authority whether there had been a simple hydrolytic action or simple inversion. The bacteria observed led to the conclusion that there existed complicated micro-biological phenomena which flourished in the high temperature in which the sugars were kept in warehouses, and which should have been avoided.

Excellent results are said to be obtained by submitting sugars to antiseptic treatment, claimed to be in no way objectionable. It was noticed that, by bringing sugars in contact with formol, they underwent no change during keeping. It has been proposed to submit the bags and boxes used for packing sugars to a disinfecting process by a hot phenic-acid treatment. Other investigators declare that these precautions are useless, as the air we breathe is saturated with the objectionable germs, and, even by the use of superheated steam in the centrifugals, the difficulty is not overcome, as the spores in question can resist temperatures of 100° to 105° C. It is a well-known fact that moist sugar is more easily attacked by the germs than pure dry sugar. From this standpoint, attention should be called to the stress BASSET[3] placed upon the desirability of keeping sugars in some very dry place. It is possible that this

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[1] Oe.-U. Z., 27, 35, 1898. [2] Oe.-U. Z., 2, 32, 710, 1903.
[3] BASSET, Guide, 3, 563, 1872.

is the reason why the HAMBURG sugar merchants give preference to warehouses built of undulated iron, and having thick planks for the floors upon which the sugar is deposited. HERZFELD[1] points out that the possible advantage of this may be due to the fact that the sugars are then submitted to all the variations of the outside temperature, and these changes are destructive to the micro-organisms contained in the mother liquor on the sugars. According to CLAASSEN, sugars with excessively supersaturated mother liquors have very superior keeping powers, for the micro-organisms cannot develop, nor even penetrate the sugar.

It is interesting to know whether or not a warehouse should be ventilated. On the one hand, HERZFELD recommends an active ventilation to cool the sugars in storage; and, on the other, E. and R. VAN MELCKEBEKE[2] declare that ventilation is a mistake. Exterior air, notwithstanding its apparent dryness, will always introduce moisture into the building, and, as the temperature is lower inside than outside, the hygroscopic conditions not remaining the same, the water in suspension will condense upon the surface of the sugars. Furthermore, the air introduced always brings with it more organisms to attack the sugar.

The use of very tightly woven bags has given most satisfactory results in keeping sugars for a considerable time without any evidence of alteration. The most recent investigations respecting the changes sugars undergo are those of Gillot, who made observations relative to the decomposition of a complex molecule of sugar into a simpler sugar molecule under the influence of diastase secreted by micro-organisms known as *Aspergillus niger* and the *Penicillium glaucum*. These secrete certain invertases capable of inverting raffinose; in fact, during the development of the *Aspergillus* the raffinose disappears entirely. It must be noted, however, that, in a perfectly neutralized medium, the spores of the micro-organisms do not develop even after the interval of a month. The alkalinity in such cases has only a retarding influence.

Considering the question from whatever point of view, the fact remains that micro-organisms play the most important rôle in the alteration which sugars undergo, the other factors being moisture, acidity, alkalinity, etc. The combined action of these elements results in the formation of a sugar that will not crystallise, com-

[1] Z., 53, 1246, 1903.
[2] E. & R. VAN MELCKEBEKE, Altération, p. 14, 1900.

bined with an increased moisture percentage, which may be followed by the running-off of a certain amount of sugar. The main object in view, when manufacturing sugar, should be to keep the sugar as dry as possible, to give it an alkaline reaction, and to store it in very dry warehouses, where air has no circulation, is not renewed, and does not come directly in contact with the sugar.

PART VI.

CHAPTER I.

WORKING AFTER-PRODUCTS.

CRYSTALLIZING TANKS.

General considerations.—The science of extracting sugar from the beet is not sufficiently far advanced to permit all the sugar to be obtained in one operation. The quantity of sugar of a given grade obtained from a massecuite depends upon numerous factors. During the swing-out in the centrifugals, from 20 to 30 per cent of after-product is obtained, the purity of which varies from 70 to 80. This is collected in a special receptacle, from which it is pumped into a waiting tank connected with the vacuum pan of the "seconds." It undergoes a slight preliminary diluting by means of steam. This after-product contains considerable sugar, a portion of which may be extracted by simple crystallization, if it is concentrated to a supersaturated condition. The ultimate object, when working the after-product swung from the first-grade sugars in centrifugals, is to obtain all the sugars in the shape of crystals not too small by means of crystallization, so that the final mother liquor is in reality a molasses.

There are four important methods of working after-products: First, by cooking, in which no crystals are formed in the vacuum pan, the crystallization taking place in the tanks with or without sugar crystals as crystallizing centres; second, cooking without crystal formation, and the subsequent crystallization in the crystallizors through cooling, or the crystallization with sugar crystals as crystallizing centres; third, the graining in pan or by the addition of crystals, and the subsequent working of the massecuites in the crystallizors; and, fourth, by returning the after-product in

some former stage of the manufacture. The time required by these different methods of working, in order to reach the composition of a real molasses, varies with the process used.

The vacuum pan used for after-products resembles in appearance one of the compartments of a multiple effect or the vacuum pan of the "firsts." In many modern beet-sugar factories, an obsolete first-sugar pan is used for this graining. But this point is of no great importance when the graining is to be conducted up to string proof, as is generally the case. When graining after-products in pan, it is customary to have in the pan suitable agitators, the arrangement of which will be discussed under another caption. The heating may be done with low-pressure steam or vapor, such as is obtained from the multiple effect.

Efforts have also been made to grain after-products by some continuous method. The PASSBURG [1] vacuum pan has a compartment communicating with the exterior, and also having a closing appliance which at periodical intervals brings it into communication with the interior of the apparatus, thus introducing new volumes of after-products to be concentrated to string proof. The closing device consists of three circular disks with notches, the middle one of which revolves around its axis, in such a way as to place the notches of the three disks in direct communication with the interior of the pan. It is claimed that this arrangement allows the pan to be emptied of low-grade products without in any way influencing the vacuum; futhermore, the operation may be a continuous instead of an intermittent one.

Reheating after-products.—Whatever be the method of handling the after-products, they must be freed from the air bubbles formed in the centrifugals while the syrup was being separated from the surface of the sugar crystals. When the product is heated to form 90° to 95° C., the air bubbles rapidly rise to the surface, and, being thus liberated, do not bring about the excessive frothing during graining in pan that would otherwise occur. During the first period the heating should be slow, and if frothing is noticed it must be kept down by the use of some fatty substance. The pan at first is only half filled, the rest of the product being gradually added.

Testing the mass.—The graining is generally pushed to string proof, and in some cases the operation is continued until the syrup has a given density determined by a hydrometer graduated at a

[1] D. Z. I., 24, 1467, 1899.

temperature of about 80° C. Most experts claim that these indications are not so reliable as the string test. If the determination is made upon the hot after-product, the results are nearly correct, but not sufficiently so to be reliable. If they were made in the sugar laboratories the data would be of no value, as they would come too late. The conditions relating to the concentration should be determined in the vacuum pan itself. The surveillance of the operation of working after-products is greatly facilitated by the use, during the concentration or graining, of appliances indicating the concentration.

It is not possible to obtain a complete crystallization of the sugar of an after-product of 75 purity by simple cooking, for these syrups must be excessively concentrated to attain that end. Consequently, when an effort is made to obtain a satisfactory extraction of sugar from an after-product, the cooking must consist of two separate operations, the first not too tight, so that the grain may be satisfactory, leaving an after-product of 65 to 68 purity, which is subsequently grained to the desired concentration.

No general rule can be given for this first cooking. The amount of water allowed to remain depends upon the purity of the product being handled, but it is always greater than that of a massecuite of "firsts." The after-product from the "seconds" should be again worked in pan for "thirds."

The conditions for the supersaturation of impure after-products are more complicated than for pure concentrated juice. While, for the latter, the condition of saturation may, from a practical standpoint, be considered as being a solution of pure sugar and the supersaturation may be calculated from the Claassen table of pure saturated solutions, the conditions of solution in after-products depend upon the quantity and kind of non-sugar present. The authority just mentioned says that the solubility of sugar is modified to a very appreciable extent by the salts, and each salt has a different action. It would seem, however, that the mixture of the substance composing the non-sugar, as it exists in the after-products of beet-sugar factories, exerts nearly always the same influence upon the condition of solubility when the proportion between the ash and the organic non-sugar is about the same, and when the juices are rationally worked. The solubility of sugar in the after-products from different factories is consequently about the same when the purity of the after-product is the same. It is only in exceptional

cases that syrups of the same purity show different conditions of saturation,—for example, when they contain heavy percentages of lime salts or raffinose, or when these after-products are rich in ash. In order to prevent misunderstanding, it is important to note that the conditions of solubility have nothing directly to do with the formation of molasses, as is frequently contended. The tables of solubility only give indications as regards the point up to which the after-products should be concentrated in order to crystallize. When the sugar is more soluble in one of the solutions of non-sugar than in the others that solution, admitting that it is purer than molasses, should be more concentrated, so that the sugar may crystallize, while a real molasses may be evaporated to the limit of dryness without any sugar crystallizing.

The influence of substances composing the non-sugar is very different at different temperatures. When, for example, an after-product of 62 purity is saturated at 20° C., it contains in solution for one part water 1.15 times more sugar than a pure sugar solution saturated at 20° C. The same after-product will be saturated at 70° C. only when it contains for one part water 1.5 times the sugar of a pure saturated solution at 70°. These data show the ratio between the amount of sugar dissolved in one part water in the saturated after-products and that dissolved in saturated solutions of sugar at the same temperature, and this factor is termed the *coefficient of saturation.*

As a general rule the coefficient of saturation is lower for all syrup at low temperatures than it is for high temperatures. In purer after-products, when the purity exceeds 70, the non-sugar exerts a contrary action at low temperatures, the coeffiicent falling below 1.0, while at higher temperatures it is always above that. Evidently the influence of temperature increases with the impurity of the after-product.

Claassen says that the variations of the coefficient of saturation of after-products of different purities and at different temperatures are still little known. We can only deduct from the experiments made approximate data, sufficiently accurate, however, for practical working.

The conditions of saturation of syrups of different purity at a final temperature of crystallization of 40° to 50° C. is of special interest. At that temperature the coefficients of saturation are as follows:

In saturated after-products of 75 purity.		1.0
do.	75–70	1.0 to 1.05
do.	70–65	1.05 to 1.10
do.	65–60	1.1 to 1.25
Under 60		1.3

The conditions of saturation at different temperatures for an after-product having a purity of about 63, which is very similar to molasses, are about as follows:

COEFFICIENT OF SATURATION UNDER VARYING TEMPERATURES.

(Parts of sugar dissolved in one part of water.)

Temperature.	In a saturated after-product of 63 purity.	In a pure saturated sugar solution	Coefficient of saturation of the after-product.
Deg. C.			
80	5.8	3.6	1.6
70	4.8	3.2	1.5
60	4.1	2.9	1.4
50	3.4	2.6	1.3
35	2.8	2.3	1.2
20	2.3	2.0	1.15

These data permit one to calculate the composition, that is to say, the water percentage of the mother liquor of molasses, which should exist with a properly conducted crystallization. When the supposed purity is 60, such a molasses cannot dissolve sugar because it is saturated, and, on the other hand, it offers but slight resistance to the crystallization, because the viscosity is reduced to the lowest possible limit. In practice the mother liquor of a molasses should be kept slightly supersaturated, so that the crystallization can continue rapidly to the end, and the coefficient of supersaturation should be kept at 1.05 to 1.10.

The following figures give the composition of a mother liquor of molasses at different final temperatures of crystallization. While they show the maximum amount of water admissible, this amount cannot be much decreased.

COMPOSITION OF MOLASSES (CLAASSEN).

Final temperature of crystallization.	Sugar.	Water.	Non-sugar.	Purity.
Deg. C.	Per cent.	Per cent.	Per cent.	
35	49.4	17.6	33.0	60
50	57.0	15.0	34.0	60
60	52.4	12.7	34.9	60
70	53.3	11.1	35.6	60

These figures permit one to calculate the most desirable concentration for after-products, after being cooked in pan, to string proof in order to obtain a suitable supersaturated molasses as a final mother liquor. It is sufficient to suppose that enough dissolved sugar has been added to the molasses to attain the purity of the after-product, and to calculate the percentage of this result. In case the after-product is to be grained in pan one should maintain during the work certain conditions of supersaturation, depending upon other factors, which will be explained later. The data relating to normal molasses serve as a guide for the realization of a desirable concentration for the swing-out in centrifugals.

Limit of exhaustion.—The concentration of the after-products should be done in such a way that the mother liquors remain supersaturated until the last, that is to say, until complete crystallization. A massecuite from an after-product should be made up of sugar crystals and a final partly supersaturated molasses. However, it is not possible to obtain through cooking of "seconds" the purity of molasses. When graining the firsts, as mentioned in Part V, one may readily obtain an after-product of about 80 purity. In Chapter IV are given descriptions of methods of obtaining after-products with purities that vary from 70 to 75. But even with such after-products it is not possible to obtain, through a second strike and the crystallizing tanks, all the crystallizable sugar contained in the product, for the reason that it would be necessary to push the concentration in pan beyond all rational limits.

Even in case the purity of the after-product separated from the seconds during its handling in the centrifugal is only 3 per cent higher than the final residuum molasses, they may advantageously be cooked again, when strict rules are followed, for the reason that a decrease in the purity of a massecuite by one unit is followed by an increase of about 1.7 per cent in the resulting after-product sugar.

Claassen recommends that impure after-products be cooked by his apparatus, keeping the operation under perfect control, in accordance with the following calculations, based upon a purity of 58 for the final residuary molasses to be obtained.

Actual purity of the after-product	68	67	66	65	64	63	62	61	60
Water percentage of the cooked product	11.5	11.8	12.2	12.5	12.8	13.2	13.5	13.8	14.1

The data for the water percentage of a concentrated after-product should be considered the highest admissible for a complete crystallization of the massecuite. It is recommended to push the concentration still further, as a protection against any conditions that may arise, and to arrange that the water percentage be from 0.5 to 1 per cent lower than is indicated in the tables. This is also recommended from another standpoint. When the massecuites are too fluid, during the formation of crystals in the boxes, even the very small crystals will rapidly fall to the bottom, and the upper layers will be lacking in crystallizing centres, and a certain viscosity is consequently necessary. The longer a high temperature is maintained in the mass the lower must be the water percentage.

Crystallizing tanks.—The massecuite is sent into the crystallizing tanks through a pipe of considerable diameter, which is thoroughly steamed out after each strike. The diluted after-product thus obtained is sent to the waiting tank of the centrifugal room. Notwithstanding the precautionary measures taken to keep this pipe perfectly clean it will frequently clog, and in some factories a trough is used for the distribution of the massecuite to the crystallizing tanks. The shape of these tanks is most varied, but their capacity rarely exceeds 10 cubic meters. Upon general principles preference is given to low tanks, as by their use the crystallization is more satisfactory. On the other hand, these flat tanks demand a considerable superficial area and require much labor for emptying. In large tanks beams or rods must be used to hold the sides in position, and there should be suitable manholes in the bottom, through which the massecuite may be drawn off. The number of tanks should be sufficient to hold all the massecuite of seconds obtained during the entire beet-sugar campaign. It is desirable to have a few extra tanks to be used in case of the emptying of one or more of the series.

For very pure after-products, such as are frequently obtained in the manufacture of crystallized sugar, the second massecuite is also run into boxes or cars that may be moved off. In sugar refineries boxes, holding from 15 to 20 kilos of massecuite, are sometimes used for the after-products. The crystallizing tanks are filled up to within a few centimeters from the top, unless excessive frothing is feared. As soon as the tank is filled the date is noted on the outside. The temperature at which the massecuite leaves the pan is 80° to 90° C., and that maintained in the crystallizing tanks depends to a certain

extent upon the nature of the product. Impure strikes always necessitate a higher temperature than pure, and this condition should continue during the entire period that the mass remains in the tanks. As the purer massecuites must cool more rapidly than the impure product there are advantages in having several rooms in which the tanks are placed, and in which the temperature may be regulated as the conditions demand. In case the massecuite is comparatively pure some experts recommend that the temperature of the room of the crystallizing tanks should not exceed 35° C., and toward the end of the crystallization it may be reduced to 20° C. For a massecuite of a lesser purity and containing less water the temperature of the rooms at the start is from 50° to 60° C. and toward the end is reduced to 30° C.

Heating of the crystallizing tanks.—The rooms may be heated either with exhaust steam or by coke furnaces. The latter are mainly resorted to after the sugar campaign has terminated and the fires of the boilers have been extinguished. The use of the lost heat from the boiler flues is an excellent plan, but it should be carried out so as not to influence the draught. For a long period of years it was customary to have numerous small stoves placed near the crystallizing tanks, but these have been abandoned owing to the danger of fire. In many factories at present well-arranged caloriferes offer a very economical means of heating. Among them may be mentioned the Martin hot-air stove consisting of several horizontal divisions made up of fire-clay bricks in the form of triangular prisms which are placed alternately one under the other. The fuel falls by gravity from one layer to the other. The prisms extend from end to end of the stove and are 1.40 meters in length.

Period of crystallization.—The period that the massecuite remains in the crystallizing tanks depends upon its purity, water percentage, the size of the tanks, and the surrounding temperature. The time may thus vary from a few weeks to three or four months. In the Wackernie[1] method for crystallization the temperature of the massecuites from after-products is lowered to 15° C. in four or five hours, and is then kept at that point for from 20 to 25 days, the temperature after 10 days being gradually raised to 23° C. The sugar in its crystallized condition falls to the bottom of the box. The temperature is gradually raised to 30° C., and after 10 or 15 days the product is worked in the centrifugals.

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[1] S. I., 8, 323, 1874.

When the crystallizing tanks contain comparatively pure massecuites the swing-out operation may be conducted during the sugar campaign; otherwise the product is held over and is handled toward the end of the summer, just before the campaign commences. Such modes of working, however, are not economical, as they necessitate starting a portion of the factory's machinery. Consequently numerous efforts have been made to introduce some method that would permit the complete handling of the after-product massecuite a few days after the sugar campaign has terminated.

Crystallization in motion by gas injecting.—With this idea in view it has been suggested to inject gas into the massecuites during the period of their crystallization in the tanks. Many years since Pieron[1] proposed that carbonic-acid gas be used for this purpose. The crystallization was thus supposed to be hastened and at the same time an epuration was effected. Ehrhardt,[2] whose method is upon the same lines, used compressed air introduced through a pipe 50 mm. in diameter, which is plunged to within 2 or 3 cm. of the bottom of the tank filled with massecuite. A rubber connection is made with the air compressor, and in this way it could be moved about in the mass and the sugar crystals adhering to the sides of the receptacle readily detached.

In a tank of 50 cb. m. capacity there was deposited a layer of 1.5 meters of sugar, and in ten minutes these crystals were made to rise throughout the mass. The agitation is not begun until the product has been allowed to rest for about 48 hours, and is then continued at intervals of 24 hours, then every 12 hours, then at intervals of 6, and finally every 3 hours. The temperature will gradually fall, and after a month will continue at 52° C. The volume of air thus injected does not reach 15 liters per hour and per cubic meter of the massecuite. It is considered that this quantity is too small to have any objectionable influence upon the crystallized mass, and the product after this treatment is sufficiently fluid to be pumped to the centrifugals. Its purity falls from 69 to 60.

The Rassmus[3] massecuite mixer for crystallizing tanks, in case the Ehrhardt compressed-air mode is used, consists of a movable car holding the air-injecting pipes. The rails are arranged along the entire series of tanks, and the car passes from one to the other

[1] S. I., 9, 357, 1875. [2] D. Z. I., 27, 2015, 1902. [3] Z., 53, 379, 1903.

as the air injecting is renewed. A rubber pipe brings the compressed air to the car, from which it is distributed through the smaller pipes introduced into the massecuite. The injecting of gas has not met with wide favor. Some special crystallizators with air motion have been built of late. However, they do not answer the purpose, as the advantage of EHRHARDT's method is to create with little expense the agitation of the massecuite in any *existing* tank. In case of a new installation the standard crystallizators in motion are to be preferred from every point of view.

Priming.—The period of crystallization in the tanks may be considerably decreased, and at the same time the yield increased, by adding to the concentrated after-product about to crystallize about 1 per cent of fine sugar crystals or powdered sugar. These crystals or sugar wastes act as priming crystals for the crystallization which begins at once, and time is thus gained in the first formaton. It is rational, when working in this way, to conduct the graining more tightly than is customary, so that the crystals that are to remain float as long as possible on the upper surface of the hot massecuite instead of immediately sinking to the bottom. By this mode of working, however, a sugar containing fine crystals, very difficult to handle in centrifugals and giving a low refining yield, is obtained.

The quantity of sugar needed for this priming increases with the impurity of the massecuite. The sugar used for priming should be of a comparatively fine grain, which, as has been previously mentioned, offers a greater surface of contact, weight for weight, than do the larger crystals. Certain manufacturers place great stress upon the regularity in shape of the crystal used.

Removal of the massecuite.—Well-formed crystals will deposit themselves at the bottom, their size depending upon chance, as it is not within the power of the most skilful pan man to obtain a strike that will crystallize uniformly. The floating molasses is almost entirely free from crystals. The removal of the massecuite from the crystallizing tank, as well as its working in centrifugals, offers no difficulty. The remaining portion of the product is readily removed from the bottom of the crystallizing tanks. The blocks of sugar attached are taken out and more or less crushed in special mixers, such as were described under another caption. If viscous, the removal of the crystallized product is difficult, and it is mainly for this reason that the use of crystallizing tanks are becoming more and more obsolete.

It is advisable to pump the massecuite into crystallizators,—when such are existing,—in which it is stirred for a certain time while being heated to 40° to 45° C., or to allow it to circulate through special tubular steam reheaters before being worked in the centrifugals. In both cases the swing-out may be accomplished without the addition of diluted molasses, and the sugar crystals are not dissolved. Massecuites, when too tight, are submitted to a preliminary mixing with hot diluted molasses, which facilitates their working in the centrifugals. Considerable sugar is thus dissolved, and as a consequence the purity of the swing-out molasses is frequently 2 to 3 per cent higher than a well-cooked massecuite.

Objections to crystallizing tanks.—Most beet-sugar factories having crystallizing tanks still retain them, on account of the expense of introducing new appliances. Modern sugar plants are built with more modern appliances at no extra cost, and with an ultimate saving in working expenses. The crystallization in the tanks is always incomplete, for the reason that the priming crystals are absent in the upper strata, as they fall to the bottom as soon as formed. Consequently, the upper layer of the molasses in these tanks always has a higher purity than the lower one. The cost of the agitating combination, with either vertical or horizontal axis, is comparatively high; but if one wishes, notwithstanding the cost, to improve the process of working the after-products, the use of first-class vacuum pans and crystallizors is to be recommended. Under the caption of Crystallization in Motion this question is more thoroughly discussed.

Frothy "fermentations" of after-products.—The working of the after-products may be accompanied by complications, such as frothy "fermentation." This phenomenon shows itself by the massecuite beginning to rise in the crystallizing tanks as soon as it is emptied from the pan. Numerous gas bubbles are formed in the mass, which cannot escape, owing to the viscous condition of the product, but which slowly rise, and the entire mass, or at least the greater portion of the upper surface, appears to froth.

Evidently the mass increases in volume in proportion to the amount of gas it contains, and the frothy portion runs over the upper borders of the boxes and the crystallizors. This liberation of gas is greatest while the massecuites are hot, and diminishes as cooling progresses, ceasing entirely at 60° C. The volume of escaping gas varies greatly, sometimes only a thin layer of scum being

formed upon the surface, while again it may form 50 per cent of the volume of the massecuite.

This phenomenon has led to numerous scientific discussions, and even to-day it is difficult to decide to what cause it should be attributed. Some experts claim that there exists an actual fermentation, while others point out that there is simply a chemical decomposition, in which micro-organisms play no part. Horsin-Déon[1] insists upon attributing it to a viscous fermentation. According to Lexa,[2] these fermentations are due to a thermophile bacillus, which he has isolated. It is in the form of twisted filament, which subsequently assumes the shape of a bacillus. The spores are readily formed, which explains their resisting powers, and begin to develop at 25° C., increasing in activity up to 50° C., at which temperature they rapidly come to a standstill. They throw off carbonic and fatty acids. According to Lippmann,[3] the production of froth in after-products should not be attributed to fermentation, but to the decomposition of sugar and organic substances.

Claassen maintains that the fact that this phenomenon is produced at temperatures higher than 80° C., at which degree all living organisms are killed, or at least show not the least sign of vitality, invalidates all theories explaining the formation of carbonic acid by the action of a ferment. He holds that the cause should be attributed rather to the decomposition of certain organic non-sugar substances, which are possibly the outcome of the decomposition of invert sugar and organic substances of considerable molecular weight, which find their way into the juices during the working of poor beets, or such as are frozen or rotten, in cases where the limited quantity of lime used during defecation has not brought about their destruction. The frothy "fermentation" never occurs when working healthy beets, but always occurs with poor beets, and when the defecation is too rapid or conducted at too low a temperature. When the products of decomposition that accumulate in the after-products are exposed to a high temperature for a long time, they continue to decompose, especially when they have absorbed oxygen from the air during their centrifugal working. One of the products of decomposition is the carbonic acid, while the other products are not volatile and are in part composed of acids which reduce the alkalinity of the after-products or render

[1] Bull. Asso., 8, 159, 1890. [2] B. Z., 22, 376, 1898. [3] Z., 38, 618, 1888.

them acid. Furthermore, there is formed a dark-colored substance which gives the massecuite and the resulting sugar a brownish-black hue. The intensity of the frothy fermentation increases with the number of times the after-products have been cooked in pan, and consequently is greater in the third massecuite than it is in the second.

GUNDERMANN[1] declares that a massecuite run from the pan at 86° C. into the crystallizing tanks undergoes a carbonic fermentation after three to five days, due to a special bacillus, which fermentation continues until the product is worked in the centrifugal, notwithstanding a very pronounced alkalinity. Formic aldehyde appears to be the only chemical that will in a measure retard the fermentation when once commenced, as many experiments, such as boiling, the addition of lime, etc., have been unsuccessful. The temperature in the midst of the fermentation is about 40° to 46° C. Keeping the waiting tanks scrupulously clean is the only practical method of preventing, or at least allaying, the difficulty.

In KARCZ'S[2] experiments, made to determine the cause of carbonic acid formation, it was noticed that the alkalinity was sufficient, and that the product contained very little invert sugar. A fact which appears rather difficult to explain is, that such vats gave from 3 to 4 per cent more sugar than those in which the abnormal changes were not noticed; however, the sugar was very dark in color. These investigations apparently show that the carbonic acid is generated, not by the sugar proper, but by the non-sugar. The complicated molecular compounds of such products are trans formed possibly into simpler bodies which no longer obstruct the crystallization of the sugar in the product.

Other observations have been made in the same direction; for example, ANDRLIK and STANEK[3] have found in certain molasses as high as 0.5 per cent of nitrogen in the form of nitrates. These molasses are acid, and, when the acidity exceeds 65 cu. cm. of normal caustic potash per 100 grams of syrup, frothing occurs. According to other authorities, this frothing originates in the decomposition of complicated organic substances, due to the action of lime upon invert sugar. These transformations must be started by certain micro-organisms, and there follows a liberation of oxid of nitrogen. By boiling 100 grams of acidulated frothy massecuite, there were obtained 170 cb. cm. of gas, consisting of 52.3 per cent carbonic

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[1] C., 6, 578, 1898. [2] D. Z. I., 23, 1653, 1898. [3] B. Z., 26, 228, 1902.

acid and 32.3 per cent of protoxid of nitrogen. As the froth does not consist entirely of carbonic acid, it is proposed to call this phenomenon nitrous fermentation. It may occur during the working of beets that have undergone certain changes in silos.

Remedies.—The remedies adopted to overcome frothing depend upon the theory accepted as to their origin. Those who believe in fermentation recommend exceptional cleanliness and washing the tanks with a concentrated solution of carbonate of soda, or, better still, quicklime. LIPPMANN [1] insists that the addition of alkaline carbonates does not correct the difficulty, but that it may be prevented by submitting the diffusion juices to an energetic lime treatment. MATEGCZEK [2] maintains that, if the after-product massecuite is not too much tightened during graining, there will be no frothing. On the other hand, CLAASSEN [3] recommends that the strike be run from pan at the lowest possible temperature. According to his experience, the yield of such massecuites is not especially affected, but the resulting sugar is very dark on account of fine grains, neutral or acid, and in most cases contains invert sugar. Consequently it has no keeping power, and is worthless upon the market, like molasses that contains more or less invert sugar.

The best method for overcoming the frothy fermentation is an energetic lime defecation of the diffusion juices. After-products that have a tendency to froth through fermentation should be grained under the highest possible vacuum, and consequently at a low temperature. If this remedy is not sufficient, the lime treatment of after-products, as before mentioned, may be of service.

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[1] Z., 38, 618, 1888. [2] Z., 24, 1040, 1874. [3] Z., 44, 613, 1894.

CHAPTER II.

CYSTALLIZATION IN MOTION.

General consideration.—In 1860 VANAERTENRYK[1] proposed that syrups be artificially cooled and grained to string proof in vertical cylinders having double sides, between which water is circulated. The same year[2] there were added to the crystallizators shaft and arm agitating attachments. This invention contains within itself all the principles of crystallization in motion. WULFF recommends that crystallization in motion take the place of the crystallization at rest. The theory advanced is that, in order to obtain large crystals, the supersaturated liquid must be constantly renewed on the surface of the existing crystals, giving a better opportunity to the sugar in a state of supersaturation to deposit on these crystals. In concentrated solutions, the crystals will readily remain in suspension, while in thinner ones they fall to the bottom of the receptacle. Consequently, the crystallization in motion should give the best results with very fluid after-product massecuites; but it is just as effective with very viscous ones, as the consistence[3] of such masses form a barrier to the crystallization of sugar.

It is evident that immediately around the crystals there is a thin layer of mother liquor, which is necessarily well exhausted of its sugar, and cannot yield any more, notwithstanding that it is in direct contact with the surface proper of the crystal. The other supersaturated layers in the vicinity will deposit their sugar only if the occasion presents itself. In a viscous environment this crystallization is difficult; consequently any motion that tends to bring the supersaturated solution in direct contact with the crystals already existing will accomplish the object in view.

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[1] La. S. B., 22, 130, 1893.

[2] AULARD, Cristallisation, p. 11, 1901.

[3] SACHS, Review, 2, 290, 1888.

The difficulty arising from the viscosity of the mother liquor cannot, according to CLAASSEN, be reduced to any great extent by any mechanical means, because the particles of syrup that adhere to the crystals, and at the depends of which the sugar should crystallize, are not by this means modified in their relation to the crystals. The principal effect of the mechanical agitation of the product is to bring about a uniform temperature and concentration, while, on the other hand, it is the diffusion alone depending upon the viscosity that brings about an equal concentration round the centres of crystallization.

Favorable conditions for crystallization in motion.—Numerous experiments have been made by HORSIN-DÉON[1] to determine the most favorable conditions for the crystallization in motion. His conclusions were about as follows: When the sugar is removed from a mother liquor, if a low purity is desired, it is necessary to start from a massecuite that has a low purity. The maximum exhaustion is obtained by leaving the minimum water in the massecuite. The desugarization is proportional to the square root of the time the operation lasts. The period for the mixing decreases as the purity of the product is higher. According to the same authority,[2] if one traces out the curve of desugarization of after-products during the mixing, it will be noticed that it is much more rapid at the start than toward the end, tending to form a parabola up to the end of the sixth hour, and to incline towards the horizontal after the fifteenth or twentieth hour. There is a rapid desugarization from the start, which becomes less and less as the operation advances and the mother liquor becomes exhausted of its sugar.

It is maintained that, by running the massecuite from pan very hot, the viscosity is lessened at a rate inversely proportional to the square of the temperature. The viscosity is one of the main causes of the parabolic curve of desugarization. The cooling must be conducted so that it will run parallel with the rapidity with which the solution is becoming desugarized; hence a product that is run very hot from pan should be rapidly cooled.

According to CLAASSEN, the cooling in the crystallizors should be done slowly, and the appliances used should have a double bottom, so as to reheat the massecuite, if it becomes necessary. The final temperature should not be too low, and cannot, as a rule, get

[1] S. I., 55, 452, 1900.
[2] HORSIN-DÉON, Traité II, 2, 719, 1900.

below 40° C. Only a moderate agitation of the massecuite in the crystallizors is needed. In most cases this mixing lasts only from one to two minutes, and is suspended then for more or less time.

Degener and Greiner have applied the same idea to a so-called crystallization at rest, but which in reality is a crystallization in motion. The mass is run into a closed receptacle, which is turned upside down at certain intervals. The crystals then slowly fall through the mass and will grow in size. Jelinek [1] claims that this idea was applied thirty years before the patent of the two experts mentioned was granted.

One of the essential conditions for a satisfactory crystallization of saccharine solutions is their concentration. Claassen very justly points out that a well-selected concentration does more for the crystallization of after-products than any motion that may be given. When the standard concentration of an after-product or a mother liquor has been determined, the essentials for a satisfactory and rapid crystallization have also been obtained, as the after-products under these circumstances have a very low viscosity. The viscosity of the after-product and the mother liquor constitute a serious obstacle to rapid crystallization, for the reason that the particles of sugar dissolved, in order to be deposited upon the existing crystals, are obliged to overcome the resistance offered by the viscosity of the after-products. When the most desirable concentration of the after-product is maintained, there is realized the least supersaturation admissible, together with the least viscosity, as this latter increases in a very marked degree with the supersaturation.

Temperature has a still greater influence upon viscosity. At 75° to 90° C., that is to say, at the regular boiling temperatures of the after-products in vacuum pan, the viscosity of pure, impure, or even saturated, after-products varies very little. At the lowest temperature, especially from 60° to 65° C., the viscosity increases much more in impure and supersaturated after-products than in purer and only partially saturated syrups. The viscosity in impure after-products may become so pronounced at the ordinary temperature that a crystallization can no longer be obtained. Inversely, the higher the temperature of crystallization the greater the supersaturation of the after-product can be kept, and one may thus decrease the period necessary for crystallization. It is possible to

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[1] La. S. B., 23, 263, 1895.

retain high temperatures only in a vacuum pan or crystallizors for any length of time, and for this reason all processes depending upon the utilization of these appliances give a much more rapid crystallization than is obtained in special boxes.

Another condition for a satisfactory and rapid crystallization of after-products is uniformity of temperature and concentration in all portions of the mass, and the presence of sufficient centres of crystallization. Later the mechanical means available for attaining a uniform repartition of temperature and concentration will be described. As a general thing, these appliances are satisfactory from that standpoint, and the centres of crystallization are well distributed and exert their desugarizing power, upon which the crystallization depends.

Crystallizators in motion.—The appliances for crystallization in motion do not differ in any important essential from the refrigerating appliances of Bocquin and Lipczinski. However, there are differences of principle and management. In the refrigerators the massecuite is simply cooled to the desired temperature for the swing-out operation, while in the crystallizator all important essentials of crystallization are closely watched. Among the Wulff patents the combinations are very numerous, but only a few of the many arrangements proposed were used. Among these are absolutely closed crystallizators, in which a vacuum is sometimes created in order to continue the graining. These appliances should always have double bottoms for their heating or cooling, as the case may be.

Ragot and Tourneur[1] point out that in these appliances only the exterior zones of the product are heated or cooled, while in the centre of the mass the temperature is entirely different. In their appliance the water or steam circulates in the interior of the agitator itself, and to accomplish this the latter has a special shape, as shown in Figs. 169 and 170. The massecuite is contained in a trough, 1, within which rotates a tubular helix, or two tubular helices, mounted on a shaft or shafts, 2, the heating or cooling fluids circulating through the helix or helices, to which the mixing paddles, 4, are attached. The shaft, 2, has at one end a hollow shaft, 6, on which a steam or water distributing box, 7, is fitted, being provided with inlet pipes for the steam and the cooling liquid respectively, and with an exhaust pipe, 35. The heating or cooling fluid passes along

[1] S. B., February, 1904.

an annular space, 13, in the pipe, 6, and thence through a pipe, 15, to the coils, the fluid finally returning through the pipe, 30, and an inner passage, 33, to the exhaust or outlet pipe, 35. In the case of

FIG. 169.—RAGOT-TOURNEUR Crystallizator.

ong troughs, two helices, 22, 23, are preferably used, their respective shafts, 2, being connected by a hollow shaft, through which the fluid circulates. In this arrangement the fluid is first caused to circulate through the coil, 22, and then through the coil, 23.

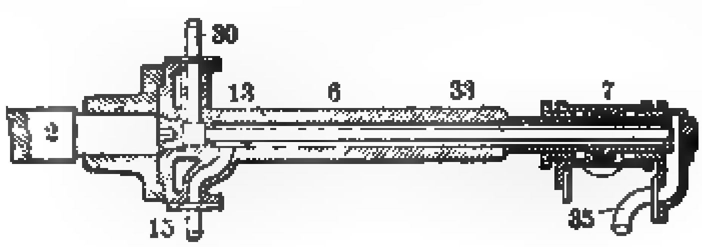

FIG. 170.—Detail of Shaft Distributor.

The HUCH apparatus (Fig. 171) consists of a closed cylindrical crystallizator, over which is a dome, D. Through the tubular clusters, B and B', circulates the steam used for heating or the cooling water, introduced through S and S'. The water of condensation is removed through d and b and the pipe E. It is to be noted that the same steam passes successively through a, b, c, and d. Between the clusters are the mechanical arm agitators, R.

The greatest objection to the general acceptance of the crystallization in motion is the comparatively high cost of the plant, and this explains, as already mentioned, why efforts have constantly been made to introduce this method in combination with existing machinery with the view to economy. HOLECKI claims that all receptacles may be changed into a motion crystallizator and fulfill, in a measure, the requisites of the situation by means of a simple

combination consisting in a spiral that will displace in a telescopic tube.[1] As the massecuite level rises in the reservoir the telescopic tube is raised. Thereby the product is always taken from the bottom of the receptacle and carried to the top, under which conditions the crystallization in motion is accomplished.

KARUTH[2] utilizes also the flat bottom massecuite tanks for the crystallization in motion. As in the former device, a vertical spiral lift is used for this purpose. The product is raised and distributed

FIG. 171.—HUCH Crystallizator.

upon the entire surface of the tank. To prevent the deposit of crystals upon the bottom, the lower portion of the spiral is shaped like a plowshare, and by this means one may at very little expense effect a crystallization in motion. It is to be noted that all installations are not so economical as they may at first appear. To put in a spiral transmission for each of the crystallizators involves considerable expense. As there are frequently more than a hundred of these tanks in a factory, the apparent economy would be doubtful compared with some rational and scientific installation.

The injection of gases into the mass, as already described, offers special advantages. In addition to what has been said, mention

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[1] Z., **53**, 439, 1903.
[2] D. Z. I., **23**, 1049, 1898.

should be made of the HRUSUKA[1] hot or cold gas mode, by which the crystallization in motion is perfectly controlled. Another method[2] of working the after-products consists in running the different strikes of the "first molasses," one over the other, in a large cylindrical receptacle, 10 m. high and 2 m. in diameter, at the bottom of which there is an agitator. As the massecuite is drawn off, the different layers sink until reaching the bottom, where the agitation begins. After eight days it may be drawn off in a fluid condition, running through a pipe into the centrifugals. It is claimed that with a product of 78 purity one obtains an after-product of 61 purity.

According to some experts, the existing crystallizators present objectionable features. The recent theory of ABRAHAM[3] is that the portions on the sides of the crystallizators are crushed by the motion, and the inner portions are motionless around the axis. The crystallizator of this expert consists of a vertical cylinder with a central axis, in which there is evolved from top to bottom a spiral scraping device fixed on the axis. The massecuite descends along the axis, and at the bottom it is projected outward by means of curved blades. It is claimed that the motion throughout the mass is all that can be desired. The same arrangement may be applied to rectangular receptacles, but is objectionable on account of the corners, which are always dead spaces.

Various modes.—If there is run into special massecuite crystallizing tanks of "seconds" a product that has been grained to string proof, and contains no trace of sugar crystals, it is evident that after a certain time crystals will form in the mass kept in motion, owing to the favorable condition of the product. This was the method adopted by VANAERTENRYK, but it has found little or no application. Later efforts were made to shorten the period of crystallization by the introduction of priming crystals into the string-proof boiled massecuites. WULFF,[4] in his patent of 1884, described a method of crystallization in motion of the after-products boiled to string proof. The strike was emptied into the crystallizators, and at the same time sugar heated to the same temperature as the mass was introduced as priming centres, and the whole agitated for a certain period. The sugar crystals, during this interval, grow in size.

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[1] Z., 50, 840, 1900.
[2] D. Z. I., 27, 2018, 1902.
[3] C., 12, 6, 1903.
[4] Oe.-U. Z., 14, 755, 1885.

The Bock[1] mode consists in leaving in the crystallizators from one-fourth to one-third of a previous strike, filling the apparatus with the massecuite from "seconds" boiled to string proof, and emptied at 75° to 80° C., after which the product is agitated for three days. This method necessarily results in the production of very large crystals, which are flat and sometimes one centimeter in diameter. They collect around the drum of the centrifugal and prevent the syrup from escaping.

In modern methods it is not customary to allow any of the previous product to remain in the crystallizators. Lippmann declares that, from the beginning, the failure of many methods of crystallization in motion has been due to allowing a portion of the product of the previous operation to remain in the crystallizing tanks. Now it is customary to concentrate the after-product either to string proof, or, by means of a brasmoscope, to a specified concentration. The massecuite is then run into the crystallizators, and, for priming, a certain quantity of first- or after-product sugar is added.

For a complete crystallization of the after-products, they should be concentrated in accordance with Claassen's table, and the data previously given for the working in crystallizing tanks. With pure after-products, which should then be supersaturated, the most there would consequently form an excess of crystals, or, if priming crystals are used, other small crystals would be formed alongside of those already existing. To obviate this, the after-products, with a purity higher than 70, should be allowed to retain more water than the table indicates, and for this reason they can never continue to crystallize so as to have the purity of a mother-liquor molasses. In reality one obtains a final after-product having a purity of 60 to 65, and sometimes more, that is to say, one that may yet give satisfactory results in tanks or in crystallizators.

As a general thing, the strikes for the subsequent working in the crystallizators are emptied with about 10 per cent of water, and the crystals are permitted to form during cooling in these appliances, or 15 to 25 per cent of sugar is added for priming. The sugar used for this purpose should first undergo a preliminary heating, or be mixed with hot after-product, so that no new crystals will be formed in the strike by the addition of cold sugar. Claassen says that it is much more rational to gradually introduce the sugar

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[1] Z., 40, 586, 1890.

into the pan than to add it to the crystallizators. The quantity of sugar used for priming necessarily depends upon the rapidity with which it is desired to conduct the desugarization, and also upon the size of the crystals one wishes to obtain. The rapid desugarization may be realized through the liberal addition of small priming crystals. To the massecuite of "thirds" 30 per cent of priming sugar is frequently added. All this is governed by the local demands that the sugar is to meet.

When sugars of after-products are intended to be sold directly upon the market, advantages are found in using for priming a higher-grade sugar than is obtained from the after-product. Do what one may, the after-product sugars are always at a lower quotation upon the market than are the standard sugars. Evidently, when the sugars are for remelts, the issue then assumes a different aspect. Under a microscope the sugars obtained from after-products, by crystallization in motion, apparently show different layers of crystallized sugar, adhering one to another, rather than large homogeneous crystals.

Duration of crystallization in motion.—The duration of this operation depends upon the extent of the sugar extraction one has in view, and the purity of the initial after-product. According to CLAASSEN, two or three days are sufficient to reduce the purity of an after-product from 75 to about 65; but, in cases where the purity is to be reduced from 65 or 70 to 60, at least 5 or 6 days are necessary. LIPPMANN[1] points out that the complete crystallization of massecuite of 68 to 70 purity should last, under the most favorable conditions, 11 to 14 days, while in the case of 80 purity the operation is completed in 5 to 6 days. The temperature of a massecuite should first fall very slowly, and then more rapidly, under regular conditions, ending by a temperature from 40° to 50° C. If a tendency for the product to thicken is noticed, the operation should cease and the swing-out operation commence. If the mass becomes viscous, diluted after-products should be added. A reheating answers the same purpose. This must generally be towards the end of the crystallization.

Care should be taken that there be no cooling during the transportation of the crystallized mass to the crystallizators. Furthermore, there should be a large crystallizator-plant in order to keep up the agitation. Where the plant is too small for the appli-

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[1] Z., 41, 450, 1891.

cation of the crystallization in motion to the "thirds," these are again cooked into the crystallizing tanks, and the product is allowed to crystallize for several months. This procedure is not desirable on account of the floor space needed for the crystallizing tanks. Modern processes, which will be subsequently explained, show that the "third" manipulation is no longer necessary, and that after the "seconds" the operation may be considered practically completed.

CHAPTER III.

GRAINING OF AFTER-PRODUCT.

General considerations.—There are methods of desugarizating the "seconds" to the condition of final molasses, even when they have a comparatively high purity. The method in question is based upon graining after-products of "firsts." For this it is not absolutely necessary that the crystals should be spontaneously formed in the midst of the product, and priming crystals may be used.

If sugar crystals are formed in the partially supersaturated after-product, or a sufficient amount of crystals is added, it is possible, if the graining is properly conducted, to bring about an active crystallization in pan, so much so that the purity of the mother liquor will fall several degrees. The difference between this method and the crystallization in motion is, that the desugarization of the after-product is effected in the pan at high temperatures in a comparatively short interval, while in the other case the operation is slow and depends upon refrigeration.

Practical hints.—One of the essential conditions for the success of the operation is, that the exact supersaturation be determined and kept within prescribed limits. The crystallization may then continue in special crystallizators in motion and the ultimate residuum is molasses. As previously pointed out, the graining in pan of an after-product does not differ in general principles from the method adopted with syrups from the multiple effect; but, as the after-product from "firsts" is less pure than the original syrup, to bring about the formation of the first crystals it must sometimes be tightened very much more than for syrups, and during graining the supersaturation must be kept higher. The crystallization is very slow, and the steam valves are only partly opened, the product being constantly submitted to the string test, or controlled by means

of a brasmoscope. MITTELSTAEDT[1] claims that no crystals can be formed with an after-product of less than 80 purity. This assertion has been practically demonstrated to be erroneous.

A difficulty presents itself in the graining of after-products which is due to the viscosity, and the dependence of this viscosity upon the temperature. The appliances, such as brasmoscopes, etc., for keeping the graining under control, in this case render great service, for the reason that, as the operation is very slow, the brasmoscope can be easily regulated according to the results expected. The devices that give rapidly the water percentage of the after-products are considered by CLAASSEN as indispensable. The concentration of the after-product, or the mother liquor, should be specially calculated for each mode of working and for products of different purity. Here again CLAASSEN uses standard coefficients of supersaturation. According to this authority, during the formation of grain the coefficient of the after-product should be about the same as for graining concentrated juices from multiple effect, and it should be gradually increased when the purity falls to 68. After the formation of grain the coefficient should at first be lessened by the suction into the pan of a small additional quantity of after-product. When the crystals have attained a perceptible size, the coefficient is gradually increased during the growth of the crystals and the decrease in the purity of the mother liquor.

Standards relating to the height of the coefficient of supersaturation cannot be given; they should, on the contrary, be calculated on the basis of the table for the water percentage to be maintained, according to the purity of the product and the stage of graining. By the assistance of this table and the controlling apparatus, the pan man is able to conduct the graining mechanically to the end of the strike. The formation of grain may be started in an after-product, when the operation is conducted by these tables or according to the string test, either as is done for the syrups of multiple effect through the suction of more product into pan, or simply by the motion of mechanical agitators. There will follow what is known as a disturbed crystallization, which during the working is regulated according to special tables, in order to obtain, with an accurately determined concentration, just the quantity of crystals wanted. No great skill is required in this method of grain formation, as the pan man need only see that the graining be not

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[1] D. Z. I., 23, 850, 1898.

continued for too long a lime. In after-products with a purity of 75 and more, sufficient nuclei of grains will be formed in a few minutes after the desired concentration is reached. On the other hand, in impure after-products, one-fourth to one-half an hour elapses before the crystals become visible. The formation of the grain may be hastened by pushing the concentration, but under these circumstances too many crystals are obtained yielding sugar of an exceptional fineness. When in excess, a portion of the crystals may be remelted, as is done during the strike of firsts in pan; but this operation demands much more care, as the crystals are most difficult to distinguish in the mass, which is rather dark in color. As soon as the number of crystals is sufficient, the formation of new ones should be stopped by a slight dilution of the mass. From that time on until the strike is completed, the degree of supersaturation is gradually increased; and this state may be determined by means of the CLAASSEN apparatus, or the use of a brasmoscope. If neither of these appliances is available, reliance must be placed on the string test. There appears to be very much less danger of false grain formation than when handling pure syrups. EGER[1] urges as a precautionary measure the heating of the after-product to 80° C., after which it is run into the vacuum pan.

The duration of graining depends upon the size of the crystals one wishes to obtain. The slower the operation, the larger will be the resulting crystals. In 24 to 36 hours a mother liquor having a purity of about 65 is obtained; but, to force this down to 60, the graining should last from 60 to 72 hours.

It does not appear rational to push the purity below 65, and when that limit is reached the product is emptied from the pan into the crystallizors.

Vacuum pans.—For graining after-products the appliances generally used are of special construction. In most cases the after-product is introduced into pan in a highly concentrated condition. As there is comparatively little water to evaporate, the motion resulting from boiling is slight, and there is necessarily a slow crystallization, hence the importance of using some form of mechanical agitation in the pan itself, or of introducing carbonic-acid gas, as previously mentioned. CLAASSEN recommends the use of dry steam, and claims for it the advantage that it keeps the mass hot—if for one reason or another the working of the pan comes to

[1] B. Z., 27, 548, 1903.

a standstill. There are needed from 500 to 600 kilos of this steam per strike. Yet another method is frequently adopted, and must be resorted to in factories where there is no special pan used for

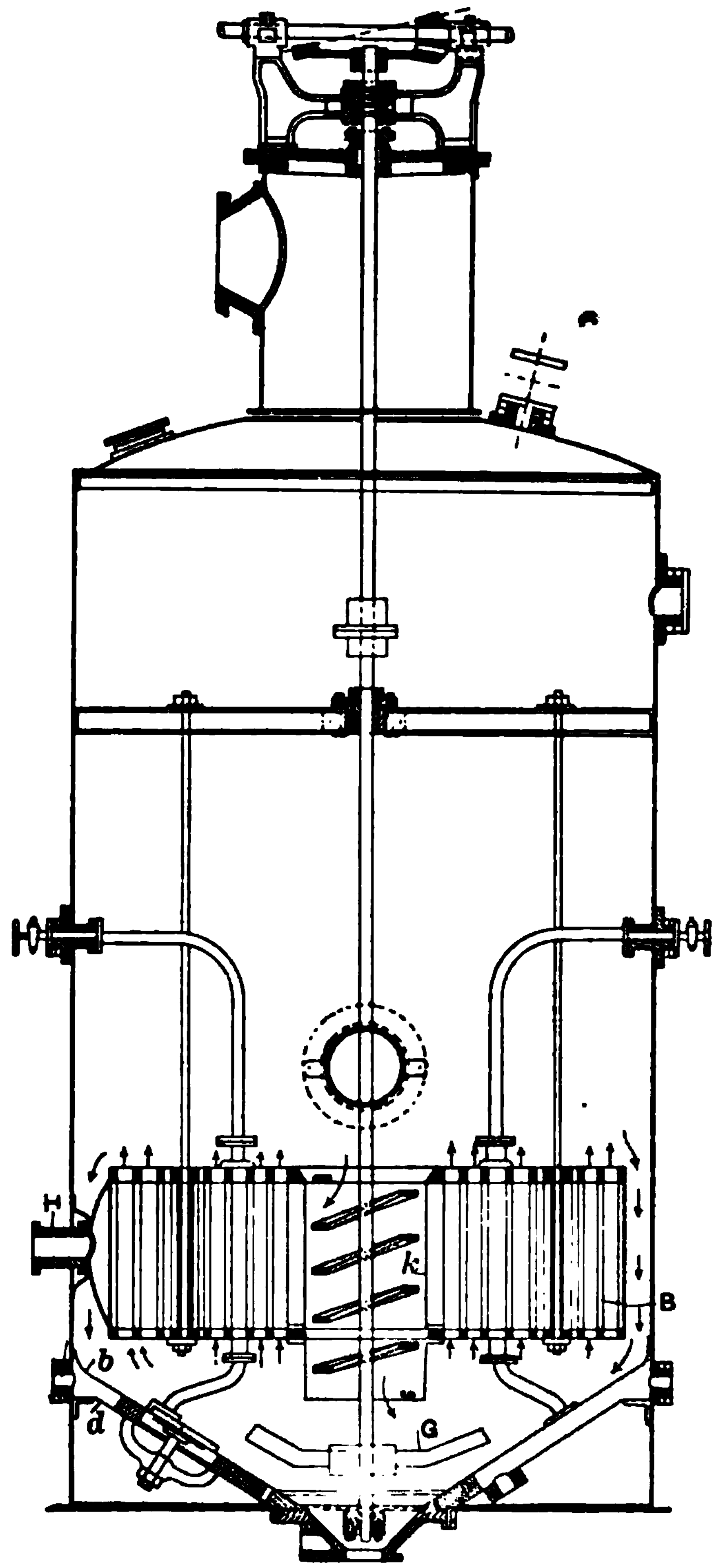

FIG. 172.—FREITAG Pan for After-products.

graining after-products. It consists in diluting the after-products to 60° or 65° Brix. The crystallization that follows is satisfactory, but an additional expense is incurred, as the water added must be subsequently evaporated.

While the REBOUX apparatus, previously mentioned, gives

excellent results for this special work, the Freitag and Grossé pans are very generally used (Fig. 172). The Freitag apparatus has a suspended tubular heating surface, *B*; the steam is introduced through *H*, and the ammoniacal vapors and condensed water escape through special pipes. At the centre of the pan there is a pipe, *k*, in which revolves a spiral that receives its motion from an upper conical gearing. The scraper, *G*, prevents the mass from collecting at the bottom, which is double, as shown in *b* and *d*, and

Fig. 173.—Grossé Pan for After-products.

may also be used as a heating surface. The massecuite is forced toward the bottom by the spiral and then rises in the interior of the tubes of which the heating surface consists. The escaping steam bubbles will tend to help this upward motion.

The Grossé pan (Fig. 173) consists of a large vertical cylinder about 5 meters in height and 2.8 meters in diameter. At the bottom are three coils, *B*, *C*, and *D*, in which steam circulates. In the centre of the apparatus is a pipe, *E*, in the interior of which revolves a shaft, *F*, with spiral agitators, which force the mass upward by means of the pulley, *G*. This shaft makes 15 revolutions per minute. To prevent entraînements the apparatus is never entirely

filled. The contents should never exceed 230 to 250 hl. of massecuite.

The Czapikowski and Karlik graining pan is horizontal. Its heating arrangement is in the shape of a cross, adapted to a hollow shaft, around which it revolves, the middle being located at about one-third the height of the evaporating appliance. The motion of the cross reheater is very slow, only 1 to 3 revolutions per minute. The heating surface is about 30 sq. m. for an approximate capacity of 30 tons of massecuite. In these heating tubes cold water may be introduced, which permits a refrigeration of the massecuite in the apparatus itself. The Berounsky [1] vacuum pan for after-products is also horizontal, and perpendicular to the tubes are arranged, depending upon the length, two or three axes with agitating arms, which revolve between the spacing of the tubes, and keep the mass in motion in every part of the apparatus, so that no dead spaces exist.

Different processes.—There are a great many methods for graining after-products that only differ in details and are changed repeatedly, according to the special requirements of the various sugar factories. It is not necessary to describe any but those that have been subjected to a practical test and are in use. By the Freitag [2] method the graining is commenced with a small quantity of after-product, this acting as a nucleus. The graining to string proof is accomplished after the mass has been submitted to a considerable tightening by introducing more after-product by suction. The strike lasts 11 to 16 hours, and is tightened so as to contain from 6 to 8 per cent of water. The massecuite remains in the crystallizators in motion for 100 to 150 hours. At intervals of two hours it is agitated for five minutes, and then the crystals are allowed to fall gradually through the mass to the bottom. After-products of 68 to 73 purity are exhausted to an average of 62, the residuary molasses having a purity of 59 to 60.

In the Czapikowski-Karlik method the graining lasts for about 36 hours. The vapors of the first and second compartments of the evaporating appliance are used for heating. After the formation of the grain the after-product is gradually introduced and the concentration continues until it reaches about 94° Brix, after which the crystallized mass is diluted by drawing in molasses. The quantity of molasses sent to the pan is about 3.5 tons, and when sufficiently

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[1] Oe.-U. Z., 32, 734, 1903. [2] Oe.-U. Z., 28, 366, 1899.

diluted the massecuite is run into the crystallizators and 3.5 tons more molasses are added. The product remains in the mixers about 72 hours and is then run into the centrifugals. The temperature before the swing-out should be about 40° C., otherwise it will be too thick and difficult to work. The massecuite in the mixers is at 90° to 92° Brix. There is obtained 50 per cent of second-grade sugar of a bright color resembling a first-grade product. A portion of the swing-out is sent to the graining apparatus to dilute the massecuite, another portion to the mixers to dilute the product run off, and the remainder is considered molasses. Its composition is about the same as normal molasses, but an average sample has a purity coefficient of 64.2, the final residuary molasses representing 1.4 per cent of the weight of the beets worked.

Claassen has attempted to establish some scientific rules and methods for the graining of after-products. He proposes the following: During graining it is important to reduce the viscosity to a minimum, so as to favor the precipitation of sugar, and this can best be done by maintaining the degree of supersaturation and temperature within reasonable limits. By the use of tables the pan man can conduct the graining mechanically. As steam is injected into the mass it circulates freely and the temperature becomes uniform. For the practical utilization of the control apparatus, when syrups are to be grained in this way, the following table is used, which gives the water percentage that the syrup should have to realize the most desirable coefficient of supersaturation for each case. This table is as follows:

Water Percentages for the Graining of After-products at Different Temperatures (Claassen).

Temperature, Deg. C.	Water percentage of syrups during graining.						
	When grain formed.			During graining.			During tightening.
	Purity = 80	Purity = 75	Purity = 70	First Period.	Second Period.	Third Period.	
70	17.3	15.2	13.2	12.5	12.0	11.5	1.0
75	16.4	14.5	12.5	12.0	11.5	11.0	10.5
80	15.6	13.8	11.9	11.5	11.0	10.5	10.0
85	14.7	13.0	11.2	11.0	10.5	10.0	9.3
90	13.8	12.2	10.5	10.3	10.0	9.5	8.7
95	12.9	11.4	9.7	9.5	9.0	8.5	8.1
100	....	....	....	....	....	......	7.7

When the temperature corresponding to the desired degree of concentration is reached the water percentage corresponds to the

most desirable degree of supersaturation, the heating ceases, the agitator is put into motion or steam is injected into the mass during one half-hour or more, depending upon the degree of purity of the syrup. When sufficient grains have been formed, the steam injection ceases and the pan is conducted under ordinary conditions, regulating the concentration, however, at different periods, in accordance with the data given in the table. If, for example, the syrup to be grained has a purity of 75 and the vacuum is 59 cm., according to the table the concentration should continue until 13.8 per cent of water is reached, requiring a temperature of 80° C.

The CLAASSEN indicator and the foregoing table give at once the temperature to which the mass should be heated for any variation of the vacuum of water percentage and purity.

When the last graining period is reached, it is recommended not to suddenly reduce the water percentage; on the contrary, dry steam is injected, which has a slightly higher tension than that existing in the apparatus. By this injection of dry steam, the mass receives sufficient caloric to compensate for losses due to radiation, as the steam abandons the excess of calories that it contained upon entering. The period of crystallization lasts for 10 to 15 hours, during which interval the steam is introduced in the calandria or coils at certain intervals, and is concluded when the water percentage of the mass is reduced to 8 or 10 per cent. The mother syrup after 36 hours has a purity of 66. The handling of the massecuites during the final period of crystallization is of special interest. The condition of supersaturation then can no longer be the same as during the first period of graining, but should be lowered.

When the graining is terminated and the product is run into the crystallizator the mother syrups are diluted, and a uniform decrease of temperature which is realizable in practice should be cared for. After the first day the temperature falls to 80° C.; after the second to 70° C.; after the third to 58° C.; and after the fourth to 45° C., and at this temperature the swing-out in the centrifugals may be satisfactorily conducted. During the cooling, there is added, per cubic meter of massecuite run from pan at 88° C., 2.6 liters of water; at 84° C. the same quantity. After that, there is added 5.3 liters for every fall of 4° C. Under these conditions it is possible to maintain during the entire period of crystallization the same coefficient of supersaturation, so that the operation takes the least possible time without reaching a supersaturation at which other crystals could form, or without attaining a condition of

viscosity which would render the swing-out operation difficult. STUYVAERT[1] claims that by this method the same quantity of sugar is obtained from an after-product in four days as is given by any of the slow-crystallizing processes in a period of weeks or months.

MATHIS is not in favor of crystallizing the after-products in pan. The grain is formed in the pan, but is allowed to develop in crystallizators. The after-products are concentrated so as to contain from 6 to 8.5 per cent of water. With the view of preventing graining of after-products that are comparatively pure before reaching the most desirable moment, the temperature is raised to 92° to 100° C. towards the end of the strike. In this mass the grain is started by forcing an agitation through the introduction of high-pressure steam or air during three to four minutes. After a very short interval the grain formation is made evident through a simple touch. At the temperature under consideration, there is only a very limited viscosity; and the crystallization that follows is very rapid, the difference of only a few degrees having a visible influence upon the crystallization, especially in regards to the size of the crystals. The larger ones being obtained at high temperatures, the product is emptied into crystallizators, and, as the supersaturation is very high, there should be an isolating exterior surface, so as to maintain the same temperature for several hours after it has been run from pan. The agitating arms of the crystallizators are kept working until the product is run into the centrifugals. After a few hours hot air is circulated over the surface of the massecuite. It is to be noted that the temperature of the air is slightly higher than the product with which it comes in contact, and the moisture is carried forward. This permits one to introduce hot diluted molasses, so as to only gradually increase the water percentage of the massecuite as the cooling progresses, and so as to slowly attain a decline in the purity of the final mother liquor. After 36 to 48 hours of agitation and cooling until reaching 75° C., the massecuite is run into open crystallizators, where the cooling is slowly continued, the diluted hot molasses being successively added, until reaching the temperature for centrifugaling, that is, 45° C. It is possible, by means of this process, to lower the purity from 77 to 60, and possibly less. The ultimate sugar obtained is said to be of very high grade.[2]

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[1] La. S. B., **31**, 416, 1903. [2] Z., **54**, 304, 1904.

CHAPTER IV.

EPURATION AND RETURN OF AFTER-PRODUCTS INTO THE JUICES.

From the time of the very first attempt to extract sugar from the beet, it was argued that it was impossible to improve the composition of after-products so as to bring them to the condition of pure beet syrups. Numerous methods have been proposed and practically tried, but have now become obsolete. They frequently reappear under another name, after having undergone some slight modification, and then again disappear. These processes, taken as a whole, may be classified along a certain line. On the one hand, the after-products are separately submitted to the action of epurating agents; on the other, the epuration takes place simultaneously with that of the normal beet juices. All, or nearly all, of the chemicals that have been proposed for epurating diffusion juices, have also been suggested for after-products. Only those will be mentioned that have shown some prospect of being successful in practice.

Epuration with lime.—The first experiments in epurating after-products with lime and carbonic acid, as applied to diffusion juices, are those introduced by Misiagiewicz,[1] in 1873. Since then the idea has been taken up by Suchomel,[2] but met with very little practical success. To Stenzel[3] is due the credit of having introduced the process in the greater practice. He diluted the after-product to 50° to 60° Brix. with the juices of first carbonatation, or with the sweet water from the filter press, and added 3 per cent of lime. He then heated and carbonatated until the alkalinity was 0.15 per cent of lime, after which the product was sulphured and filtered on wood wool.

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[1] Oe.-U. Z., 2, 457, 1873.
[2] Oe.-U. Z., 17, 61 and 159, 1888.
[3] Z., 48, 1007, 1898.

The after-product thus treated may be grained to white sugar. It is claimed that by this method a characteristic epuration of the after-products is obtained, and the scums contain a high percentage of nitric bodies, with frequently 15 per cent of organic substances. The lime causes a physical amelioration, such that the viscosity is no longer a difficulty, and the product readily yields "seconds" and "thirds."

Sulphuring after-products.—In many beet-sugar factories it is customary to sulphur the after-products before submitting them to a second crystallization. This operation is of service in reducing excessive alkalinity. But when the syrups from the multiple effect have been saturated, so that their alkalinity varies from 0.02 to 0.04, and the first massecuites have consequently an alkalinity of about 0.05, that of the after-product is approximately 0.05 to 0.10. According to CLAASSEN, an alkalinity of at least 0.05 is not objectionable, but is, on the contrary, absolutely necessary, in order that the alkalinity of the after-product may not decrease and become neutral during the long period of crystallization in the tanks, the vacuum pan, or the crystallizors, which lasts for days at a time. The saturation of the after-products, therefore, is not necessary in the usual methods of working, and may be omitted, as in such cases the dilution and subsequent evaporation of the products add to the cost of working.

Many experts differ with this authority as to the question of alkalinity, but when the work is rapidly conducted their fears are no longer justified. For many years numerous factories worked with considerable acidity. The STEFFEN and DRUCKER methods are examples in point, and no difficulty resulted in the crystallizing tanks.

CZAPIKOWSKI and KARLIK [1] work with after-products having a purity of 78 to 81. These are diluted to 62° Brix. in a carbonating tank; lime is added until the alkalinity is 0.2 per cent, and the temperature is then raised to 90° C. The after-products are sulphured until there is only a slight alkalinity when tested with phenolphtalein. The quantity of lime used is about 40 kilos for a 550-ton plant. After sulphuring, the after-products are run through a sand filter. Experience shows that the decolorizing effects of this epuration are proportional to the amount of lime used, but this must be limited because of the filters. The advantages claimed for the method are a good yield and an easy curing of the massecuites.

[1] B. Z., 27, 421, 1903.

In the RAGOT method the first after-products from centrifugals are diluted to 27° Bé. Then 0.1 per cent of lime and 0.05 per cent of "Kieselguhr" are added, and the mixture is sulphured until the reaction is neutral with the phenolphtalein test. With litmus-paper, however, the reaction is alkaline. The sulphuring is done by the continuous QUAREZ method. The crystallizing boxes are rather high, as there is a constant frothing tendency after sulphuring. The after-products thus treated are of a light-yellow color, and possess a sparkling appearance. Their crystallization is satisfactory.

Various modes of epuration.—Mention may be made of the RANSON process, in which hydrosulphurous acid is used, though this mode has to-day become almost entirely obsolete, and the same may be said of the use of ozone as an epurating agent. GERBRACH and WIECHMANN[1] proposed to boil the swing-outs from second-grade sugars with the oxid of an alkaline earth. Precautions must be taken to keep the temperature of the pan as low as possible, and under these circumstances certain volatile substances are liberated. An excess of an acid is added, for which purpose phosphoric or sulphurous acid may be used. The bases will be precipitated and the organic acids set free. After a second working in pan these are volatilized, and filtration, concentration, etc., follow.

The SCHULZE method of working after-products consists in adding baryta and submitting the combination to a carbonatation. The filtration that follows is intended to separate the baryta carbonate. MITTELSTAEDT[2] recommends special treatment for low-grade syrups that are to be worked in pan. The first operation consists in diluting them with water, adding 3 to 5 kilos of hydrated baryta and 10 kilos of carbonatation scums to a volume of cne cubic meter, and then submitting the mixture to a sulphuring, so that the alkalinity is reduced to 0.02, expressed in lime.

The BOOT[3] method consists in submitting the after-products to a preliminary heating at 50° C. in a special apparatus with an agitator. To the heated mass 5 to 25 grams of zinc per hl. are added; sulphuring follows until a point of decided acid reaction is reached. After the syrups thus treated become colorless the temperature is raised from 75° to 95° C.; a ferro cyanid is added, to precipitate the zinc and traces of iron which frequently cause discoloration of sugar.

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[1] Oe.-U. Z., 28, 52, 1899. [2] C., 7, 977, 1899. [3] D. Z. I., 24, 1751, 1899.

If the syrups are not sulphured they should be first heated, and then combined with 2 to 10 grams of the ferro cyanid per hl. of product. The organic precipitates are subsequently eliminated by filtration.

Böcker has proposed to add to low-grade syrups alumina sulphate, and then 3 per cent of lime. The liquor is heated to 80° C. (176° F.) and mixed with 1 per cent of barium chlorid, followed by a thorough agitation. It is claimed that the alkaline bases are fixed, and probably most of the calcic organic salts are surrounded by hydrate of aluminum.

The Harm method has been applied not only to diffusion juices, but also to after-products. The different electrolytic methods have been tried on after-products with more or less success. The Cassel and Kempe [1] process has been especially proposed for these products. It is based upon electrodialysis and possesses the following special characteristic: An akaline salt is introduced into the cell of the anode, so that it is carried by the current into the electrodialyzed after-product and prevents the hydrolysis by the acids. Up to the present time, such methods have met with very little practical success.

Filtration of after-products.—A filtration before graining is frequently considered advantageous, as the after-products are always more or less cloudy, owing to the precipitations formed during their working in the vacuum pan. But as the weight of these precipitates is extremely small and the filtration of after-products is always difficult, even when they are diluted and mixed with porous substances, the utility of the operation is doubtful, according to Claassen.[2]

On the other hand, it is claimed that after the dilution with water the product at once becomes cloudy, and the same change is noticeable under the influence of sulphuring. The total precipitation may reach 0.182 per cent of the dry substance; however, in practice, this is seldom more than 0.04 to 0.045. Notwithstanding that this very small quantity has no important influence upon the purity, its effect upon the crystallization is very marked. The precipitate formed consists of organic salts of lime and iron, silica, and fatty substances. Oxalic acid may exist in quantities corresponding to 10 to 25 per cent of the total. Under these conditions the yield may be increased from 3 to 5 per cent by diluting the molasses to 60° Brix.

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[1] D. R. P., 78, 792, 1893. [2] B. Z., 26, 433, 1902.

According to MARES, the filtration of after-products for the purpose of eliminating all mechanical impurities does not increase the purity coefficient, and no epuration properly speaking is realized, but there is a decided increase in the yield of crystallized sugar. The sugar has a high polarization and the molasses a low purity. The deposits on the filter presses are a gray-green and viscous. However, according to NEUMANN, they contain 63.5 per cent of sugar and an actual purity of 76.4. One and one-fifteenth per cent of albuminoid substance may be an obstruction to the crystallization of these products. The filtered after-products have a fine rosy color. KARLIK claims that, with a normal filtration, the after-products cannot contain any solid impurity, and if not diluted with water—even with distilled water—they become cloudy. The very small quantity of foreign substance that is thus precipitated, according to this authority, renders the syrups viscous, and when this is removed through filtration the sugar yield from these products is increased. It is consequently recommended to dilute the after-products and then submit them to a thorough filtration. ANDRLIK [1] points out that in concentrated syrups the non-sugar is in solution owing to the reciprocal action of one upon the other, the sugar upon the non-sugar, and that on dilution the equilibrium existing between them is destroyed and the non-sugar is again precipitated.

Return of after-products.—There are numerous processes in which the after-products are returned to the juices during one of the phases of sugar manufacture. For example, it has been proposed to introduce them into the diffusion battery, the juices, the defecated juices, the carbonatation tank, during sulphuring, into the syrups as they leave the multiple effect, and finally into the pan during graining. As this is of greater importance than the other methods, it may be separately treated. Among these numerous processes, the return to the juices in the diffusion battery and during defecation have been the most in vogue.

Return to the diffusion battery.—MANOURY [2] took out his patent in 1885 for the return of the after-products to the diffusion battery. They were introduced without any special preliminary epuration and mixed with the beet slices in the diffusors. There followed an osmotic action, just the reverse of that which exists in the diffusion. As the percentage of saline substances is higher

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[1] B. Z., 25, 564, 1901. [2] Bull. Asso., 15, 907, 1898.

on the exterior than in the interior of the cells of beet slices, there follows an osmotic pressure which tends to establish an equilibrium between the two different solutions. The saline substances will consequently pass from the juice into the beet cells, thus effecting an epuration of the after-product. The crystallization that follows will be greatly facilitated, and the results obtained are very different from those that would have followed had the after-product been added to the juices after they left the battery. This method had considerable vogue in Russia and met with some success in France.

MANOURY points out that the process gives an increased yield of 2 per cent of the weight of the beet in first-grade white sugar, and a final higher yield of sugar with a decrease in the percentage of molasses. One of its objectionable features is the necessity of drawing off more than the usual volume of juice from the diffusor. Although the combination of after-products with beet pulp [1] was proposed in Belgium before 1853, it had nothing to do with the principles of this mode. This same expert proposed to introduce rich after-products obtained in the white-sugar manufacture in the juices before first carbonatation, they having previously been made alkaline through the addition of either lime, strontia, or baryta, preference being given to the latter on account of its greater activity. There is added to the diffusion juices from 2 to 4 per cent in volume of this diluted and prepared after-product.

In the ZSCHEYE [2] method, from 2.5 to 3 per cent of lime and 1.56 per cent of neutral after-product at 70° Brix. were added to diffusion juices heated to 75° to 80° C., which after a thorough mixing were carbonatated to an alkalinity of 0.1 to 0.12 per cent of lime; 0.04 per cent of barium chlorid was added (calculation made upon the weight of the beet), and this was followed by filtration. During second carbonatation, 0.5 per cent of lime is added; a carbonatation until the alkalinity is 0.07 to 0.08 follows, and then a sulphuring until it is 0.05. After filtration the alkalinity is brought to 0.02 by means of carbonic and sulphurous acid.

ANDRLIK [3] points out that the return of the after-products to the ZSCHEYE carbonatation only gives a slight increase of purity. The scums contain only very small quantities of salts, and there is no separation of nitric substances existing in the after-product.

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[1] Z., 3, 334, 1853.
[2] STOHMANN, Handbuch, 558.
[3] B. Z., 23, 65, 1898–1899.

This authority insists that the repeated cooking necessarily results in considerable sugar losses. In the primitive methods of the LOEBLICH[1] brothers, after-products of a purity of 70 to 72 were neutralized by hydrochloric acid, heated, and returned to the juices during defecation. In order to obtain the maximum epuration, these experts recommend dry-lime defecation. For special reasons this process underwent some change, and their more recent method consists in returning to the juices the after-product from "firsts" with a minimum purity of 76, and submitting them to a preliminary heating at 95° to 100° C. It is claimed that a precipitation of the non-sugar follows. The numerous processes in existence are variations of the STENZEL, ZSCHEYE, and LOEBLICH methods, which have, during comparatively recent years, met with some favor.

Advantages of these processes.—All these methods have in view an epuration of the after-products which will permit them to crystallize more readily. The actual realization of this epuration has been much discussed, but, argue as one may, the plan leads to an increase in first-grade sugar yields.

CLAASSEN says that the lime in this case acts on the non-sugar under exactly the same conditions as it does upon fresh juices, it becomes evident that one cannot by this treatment obtain an epuration unless the previous defecation of the diffusion juices has been neglected, or effected at too low a temperature. It has never been demonstrated that the purity is increased by the action of lime upon the after-products, but, on the other hand, the treatment appears to facilitate crystallization, which is an important advantage that should be taken into consideration, and one that in some cases compensates for the trouble of saturation, filtration, and the additional expense.

BOECKER,[2] on the other hand, claims that there results an elimination of non-sugar and organic substances; for, if such were not the case, it would be impossible to continuously introduce the after-product during a certain phase of working, and the work would come to a standstill after a very limited period, on account of the accumulation of impurities. Experience shows that the massecuites are perfectly normal. It is further claimed that the physical condition of the after-products is changed, and hence they crystallize more readily. This was at one time contested by CLAASSEN,[3] but his ideas on the subject have since changed.

[1] Z., 48, 736, 1898. [2] D. Z. I., 23, 1187, 1898. [3] C., 7, 348, 1899.

Schnell's[1] experiments demonstrate that all the methods for the epuration of after-products are necessary when the beet juices have been submitted to the standard normal treatment in the factory; that is to say, at all the stations the juice is very clear and has a suitable alkalinity.

The return of the after-products into ordinary or very pure juices acts most favorably during graining, partly because the time required to obtain the desired results is increased in proportion as the purity of the concentrated juices thus mixed and grained is lowered. If, for example, the amount of after-product added reepresents 3 per cent of the weight of the beets sliced, and has a purity of 78, the purity of the concentrated juice that was 92 falls to 90. Slow graining increases the sugar yield.

Better results are obtained by introducing the after-products nto the vacuum pan proper rather than by mixing before the graining has been started. The addition should be made towards the end of the strikes started with pure concentrated juice. This method is always applicable, while the one first mentioned should be used only for very pure juices; otherwise the resulting grains will have an ugly shape and the sugar obtained will be of an inferior quality.

Objections.—Numerous complaints have come from refiners that, since the return of after-products to some phase of sugar extraction has been in vogue, the appearance of the sugar crystal is not satisfactory. Lippmann considers that these complaints are justified. Without doubt, all foreign substances contained in the beet influence the shape of the sugar crystal, and, such being the case, there does not seem to be the slightest doubt that these foreign substances tend very decidedly to change the shape of the standard crystals. On the other hand, as the after-products, when introduced in pan, come in contact with a crystal that has a definite shape, the influence of impurities can be of only secondary importance.

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[1] C., 11, 756, 1903.

CHAPTER V.

RETURN OF AFTER-PRODUCTS INTO THE GRAINING PAN AND CRYSTALLIZATORS.

Historical data.—The returning of the after-products to the pan and crystallizators appears to have been first suggested by WULFF, but his pan was entirely different from that which is now in practice. It was noticed that the lower portion of the after-products in the waiting tank contained a considerable quantity of crystals, some of which had escaped through the wire cloth of the centrifugal drum during the swing-out, while the others had been spontaneously formed. The idea was to remelt these crystals, and to force them to crystallize upon first-grade sugars obtained from pure beet syrups. The procedure was about as follows: [1]

A portion of the after-product from a previous strike, containing crystals that had escaped from the centrifugal, was returned to the vacuum pan. These after-products were taken back until the volume of mother liquor treated became too great. The lower decanted portion, still containing a certain number of crystals, was removed, and the upper portion of the after-product was boiled to string test.

In methods subsequently introduced by RAEYMAECKERS [2] it was proposed to handle the vacuum pan as usual, but to resort to considerable tightening. As these massecuites were difficult to remove from the vacuum pan, it was recommended that a certain quantity of low after-product be drawn into pan, thus facilitating their removal.

The STEFFEN-RAEYMAECKERS systematic graining process consisted of allowing the purity of the mother liquor to fall gradually by feeding the crystals with syrups according to the actual composition of the mother liquor at each introduction of syrup. By the regular process of graining "firsts," every introduction of new

[1] N. Z., 26, 209, 1891. [2] La. S. B., 19, 434, 1891.

syrups has the effect of increasing the purity of the mother liquor of the mass being handled, while, on the other hand, the crystallization tends to decrease the purity of the mother liquor, this being the main object in view. These two actions, working in opposite directions, are more and more pronounced towards the end of the graining, when the mother liquor is at its lowest purity. The inventors [1] declared that there was a constant danger of new crystals being formed in the comparatively pure medium, a phenomenon which could not exist if the purity systematically decreased. Consequently, if there are introduced into the mother liquors syrups of about the same composition as the medium in which the crystallization was being effected at the moment considered, the mother liquor obtained would be more thoroughly exhausted of its sugar. The practical working of the process was about as follows:

The first part of the graining is with syrup, and the crystals formed are the nuclei of the future crystallization. Portions of syrups of decreasing purity are successively introduced to feed the grain. Under these conditions there will remain, towards the end, only very inferior syrups, which may be almost entirely exhausted of their crystallizable sugar. The new formation of small crystals is thus obviated, while the mother liquor is systematically exhausted up to the maximum limit. To obtain a series of syrups of constantly decreasing purity, there are advantages in introducing STEFFEN's mode of refining, which will be described under another caption. If refining is not done in the factory, the syrups of the desired purities may be obtained by combining in the proper proportions the after-product with pure syrups.

RIMBAULT [2] recommends that the entrance valve to the pan for the after-product be gradually opened, while that for the pure syrup be gradually closed. The newer patent of STEFFEN and RAEYMAECKER is very different, and from a practical standpoint has many advantages. The idea on which it is founded is as follows: If one wishes to transform a massecuite into crystallized sugar and molasses, it is necessary that, in the composition of the mother liquor, the water and the non-sugar be in the same relative proportions as in molasses, that is to say, as 1:2. This proportion does not in general exist after the final tightening. Two methods have been proposed to attain this result. The first consists in reducing the water in the massecuite, but a hard, dried product results, and

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[1] La. S. B., 20, 132, 1891. [2] S. I., 48, 680, 1896.

so preference is given to increasing the quantity of non-sugar in the product by introducing after-products until the purity falls to 82. The tightening then is to the limit of 7 to 8 per cent of water, under which conditions the proportions between the water and non-sugar is as 1:2.

MALANDER says that in a factory at Ghent (Belgium), during 1894–95, the graining was commenced in the ordinary way. The tightening was excessive, leaving only 4 per cent of water. The after-products, diluted to 60° Brix., were introduced, the volume depending upon their purity and that of the massecuite, the final mixture having a purity of 82. The graining was completed so that there remained from 7 to 8 per cent of water, and the product run into the crystallizators, where it was agitated for from 18 to 20 hours. During the cooling there was introduced an after-product at 60° Brix, so that the average water of the mass was 8 per cent.

At the same period the MANOURY method was made known, and later complicated litigation was begun as to the priority of the patents. Numerous factories in France were paying a royalty and others were not. The indemnity that this expert could have claimed would have been enormous, but upon some trifling detail the case was decided against him. The process was combined with the manufacture of superior white sugar in the factory. By it are obtained two forms of after-products of different qualities, that is, the regular "first molasses" and the rich after-products resulting from the washing of the sugar. The graining is conducted as usual with syrup from the multiple effect until the pan is two-thirds full, when the rich after-products are introduced, and, after the entire quantity from a previous strike has been added, the regular after-products are drawn in, filling the remaining one-third of the pan. The tightening continues until there is from 6 to 7 per cent of water in the massecuite. Later MANOURY recommended that the tightening be stopped with 8 per cent of water. The strike is run into refrigerating appliances and water is added, in the form of diluted after-products, to redissolve the small crystals that may have been formed, and to maintain the fluidity and the purity of the mother liquor, as they existed in the massecuite when it left the pan. The centrifulgaling commences when the temperature of the mass is at 40° C.

The processes that have been the outcome, directly and indirectly, of this idea, are very numerous. In fact, while each beet-sugar factory works upon some variation introduced by its techni-

cal manager, it is always possible to see its similarity to the method just described.

The greatest variation exists in the period at which the after-product is added. In some factories the crystal is allowed to reach a certain size, approaching its limit, before the after-product mixing, and under these circumstances the volume added is comparatively small. On the other hand, the after-product is sometimes drawn into pan just at the instant when the grain begins to be visible; in this case the volume added to the massecuite is quite large, and a second-grade sugar that is crystallized around the nuclei of "firsts" is obtained. The reverse occurs in the first case, for then the large crystal is simply fed with that furnished by the after-product.

At the Meaux (France) beet-sugar factory, both of these modes as adopted by Ragot are applied. The graining of firsts is about the same as already described, but with the difference that the coefficient of supersaturation is never allowed to exceed a certain limit. When the grain has been well-formed, about 40 per cent of the after-product is drawn in, having been previously diluted to 35° Bé., and submitted to a certain epuration described under another caption. The strike when finished is at about 85° C., and contains about 10 per cent water, that is to say, it has not been tightened. It is cooled after seven or eight hours to 45° C., and is then run into the centrifugals. White sugar being made, the swing-out from centrifugals is divided into after-products from "firsts" and rich after-products. The rich after-product is mixed with the syrup from the multiple effect, the green molasses being diluted, epurated as previously described, and, to a limited extent, introduced into pan during the graining of "firsts." What remains is separately grained. The strike is finished at 85° C., with 10.5 per cent of water. It is cooled, and after 36 hours has a temperature of 30° to 40° C. and is centrifugated. The swing-out of "seconds" has a purity of 58 to 59, and may be considered as molasses.

The Huch and Lauke process may also be cited. The massecuite in this case is excessively tightened, and is run into closed crystallizing tanks with suitable agitators, described under a previous caption. This mass contains a certain number of small crystals, which will be used to feed the larger crystals. With this idea in view, a quantity of water is drawn into the pan to dissolve the small grains, and then follows a slow boiling in the crystallizator, which is put in communication with the condenser to this end. The

mother liquor is concentrated, and the sugar of the redissolved small crystals will deposit on the larger ones. Later, with the idea of dissolving the false grain, diluted after-product was used instead of water, and little by little the method was changed to that of graining in pan with after-product introduction. It is interesting to note that it was in the HUCH and LAUKE closed crystallizators that the principle of carrying the massecuite by compressed air and vacuum was first introduced.

Special conditions for graining.—As after-products will not crystallize with the same rapidity as pure beet syrups, certain conditions must evidently be maintained in the pan in order to bring about the object in view. It has already been explained how important it is in such cases to keep the mass tighter; the coefficient of supersaturation should be somewhat higher, and the duration of the strike longer. As the quantity of water to be evaporated is proportionately less than with standard syrups, and as this obstructs the crystallization, the product being not kept in motion, it is advisable to dilute the after-products to 35° Bé., unless suitable graining pans with agitators, as previously described, are available.

In some factories it is customary to conduct the graining under particular conditions. From the moment the grain is sufficiently developed, there are alternately introduced into the pan after-products and syrups from multiple effect, and the strike is completed with the final introduction of after-products. This procedure is a mistake. The only correct way, used almost everywhere at present, consists in developing the crystals into a given size, to tighten the mass as much as possible in order to lower the purity of the mother liquor, and then to continue the strike with the after-product.

Working of mixed massecuites.—The handling of mixed massecuites demands more attention than that of pure syrup, as any mistake committed causes serious difficulty during the swing-out operation, CLAASSEN recommends two different methods for working in the crystallizators. In one case the massecuite is emptied from the pan with a mother liquor of a certain concentration, so that the coefficient of supersaturation shall be about 1.3. A product of this kind containing from 6 to 7 per cent of water cannot at first be cooled, but should be kept for several hours at 75° to 80° C., its temperature when emptied from the vacuum pan. The supersaturation is then so high that new crystals would be immediately formed if it were increased by cooling. It is only when

the coefficient of supersaturation has fallen to 1.2, owing to the crystallization, that gradual cooling is possible. When the temperature has fallen to 60° C., after from 18 to 24 hours, the diluted after-product can be added continuously until the mass with which it is mixed becomes sufficiently fluid to be worked in centrifugals. The work is completed when the temperature has fallen to 55°.

As one may commit certain errors in the handling of very tightly grained massecuites, experience shows that there are many advantages in having them of a certain dilution. Evidently, in this case, the product may also be tightened, so that the mother liquor has a coefficient of supersaturation of 1.3, which is recommended as a standard. After the pan is emptied, the water resulting from steam cleaning may be allowed to run into the crystallizators, or a certain quantity of hot diluted after-product may be added, whereby the supersaturation of the mother liquor will fall to 1.5 or 1.2. This moderately tightened massecuite contains from 8 to 8.5 per cent of water, and may be cooled at once and in a reasonably short time, under which circumstances, after 15 or 20 hours, it may be advantageously handled in the centrifugal, when the temperature has reached about 50° or 55° C. By this method of working, no false grain will be formed, and there is no necessity of diluting the grained mass; less sugar, however, is obtained than with a tightened and non-diluted product.

Limit of exhaustion.—By the usual working of light massecuites, the purity of the after-product is 75, and even this is attained only when the tightening operation continues over a long period with after-products in pan, while, with a tightly grained mass, the purity may fall below 70. This condition demands considerable attention, and, unless it is given, the final massecuite is difficult to work in centrifugals, and, to be satisfactorily handled, must be reheated and diluted, which always causes a remelting of sugar, and results finally in a decrease in yield.

Apparently there is no advantage in pushing the sugar crystallization of a mother liquor too far, that is, in a first massecuite, for the reason that too large a number of vacuum pans with agitators and crystallizors would be needed. Usually a purity for the after-product of 75 is considered satisfactory; very few sugar factories get lower than 70 or 72, while many, on the other hand, remain above 75. In order to obtain perfectly white sugars, the desugarization of the after-product should not be pushed too far.

Return of the after-products to the crystallizators.—The method that has been just described necessarily demands a considerable number of vacuum pans or appliances of exceptional size. STEFFEN and RAEYMAECKERS proposed to overcome the difficulty in the application of their process by adding after-products to the massecuite in the crystallizators, so that the purity of the mass is lowered to 82. Other inventors have proposed to add to the crystallized mass in the crystallizators variable quantities of concentrated after-products which have been concentrated separately. The work of crystallization that has been started in the vacuum pan is continued in crystallizators, in which the product is boiled further. In reality, as there is no method of controlling the exact saturation, new crystals are always formed, which should be dissolved when brought in contact with the diluted after-product, and this evidently complicates the regularity of the crystallization. It is for this reason that one does not practically obtain by these processes better results, as when the saccharine solutions are crystallized in the vacuum pan and simply cooled down in the crystallizators.

Importance of eliminating part of the after-product.—If all the swing-outs from the centrifugals during the handling of the "firsts" were continually returned to the massecuite, the volume of the final mother liquor would attain enormous proportions after a very few days. A certain portion must consequently be put to one side to produce the "seconds," and the factories differ in their arrangements for effecting this. In some cases all the after-product is put aside after two, three, or four strikes; others boil into the crystallizing tanks a portion of the after-product from each strike. There are many arguments for and against these different methods.

CLAASSEN[1] has made a series of experiments to determine just what the conditions are for the boiling of a juice that has been several times taken back. It was concluded that the evaporation of the concentrated pure and impure solutions demands a comparatively great fall of temperature, which must be increased with the number of times the graining has been repeated. It is to be noted that there is no special variation in the chemical composition before and after graining. On the other hand, with diluted solutions, a fall of a very few degrees is sufficient to keep up an active boiling, while, with concentrated solutions, the boiling ceases with a fall of temperature varying between 16° and 27° C. A strange fact

[1] Z., 53, 333, 1903.

noticed is, that molasses is more readily cooked than purer after-products, the concentration of which offers certain difficulties. This would tend to show that the difficulty is caused, not by the non-sugar alone, but by its combination with the sugar. This difficult concentration prevents vapor bubbles from forming with a slight fall of temperature. Neutral solutions of sugar will boil readily under normal conditions only after the first graining. Alkaline solutions have keeping powers, and can be cooked after having been submitted seven times to this operation. The viscosity does not correspond with the difficulties of graining. When to diluted after-products lime is added, the viscosity will be diminished, but not the difficulties of working. To conduct a graining under satisfactory conditions from first to last CLAASSEN says that the fall of temperature should be at least 25° C. The steam should be at a pressure of at least 0.25 of an atmosphere for the "firsts," and from 0.4 to 0.5 of an atmosphere for after-products, supposing that the heating surfaces are sufficient to boil slowly, and that some mechanical means are adopted for assisting the action of the steam. For water to boil, there must be a difference of temperature corresponding to about 6° C. For saline solutions, this difference is very much less, while, for solutions of calcium chlorid, it varies from 2.4° to 4° C. This explains why molasses boils more readily than after-products.

CHAPTER VI.

CURING AFTER-PRODUCTS.

Practical hints.—Massecuites from after-products may be separated into mother liquor and sugar of more or less purity by all the processes that are applied to "firsts." However, the centrifugating presents certain characteristic features. The drum of the centrifugal is gradually filled during its full working. If th› feeding of the load is too rapid, the molasses can no longer find its way through the sugar, which causes a marked oscillation of the apparatus. This motion largely depends upon the viscosity of the mass being handled; hence the load in the drum must be smaller than in the case of massecuite from "firsts."

The completion of the operation is ascertained by simply placing the shovel of wood between the outer casing of the centrifugal and the drum, in which case no more molasses are projected upon the shovel, or by holding it against the sugar in the interior of the drum. If the operation is finished, there will be a white impression; if, on the contrary, it is dark in color, the spinning must continue. Care must be taken by such tests that the shovel is not held in the opposite direction to that of the centrifugal's motion; otherwise accidents are apt to occur.

It frequently happens that when the mass from after-products is too viscous, and the sugar crystals are not of the proper shape, the sugar cannot be separated during the centrifugaling, and one must then resort to dilution or heating to lessen the viscosity. The after-products obtained with the priming sugar of "seconds" and "thirds" frequently are difficult to centrifugate, on account of the very flat shape of the sugar crystals.

Draining after-products.—During a period of years, centrifugating was confined to "firsts," and the "seconds" were allowed to simply drain off from the SCHUEZENBACH boxes. While this idea went out of vogue for a time, a number of French factories have of late years again introduced it under a modern form. In the

DUFAY method, the after-product from "firsts" is grained to string test and sent to crystallizating tanks, which are very high and long but narrow, and have a trapezoidal section. They are cooled by a current of air, and the crystallization lasts twenty-four hours. At the bottoms of these crystallizating tanks are wire cloths and plugs to allow the draining off. The wire cloths are cleaned with a jet of steam, and the massecuite is allowed to drain for twenty-four hours. The drained mass is reheated with live steam, and then again allowed to drain for fifty-six hours. The second carbonatation juices are introduced into *J* (Fig. 174) through the valve, *N*.

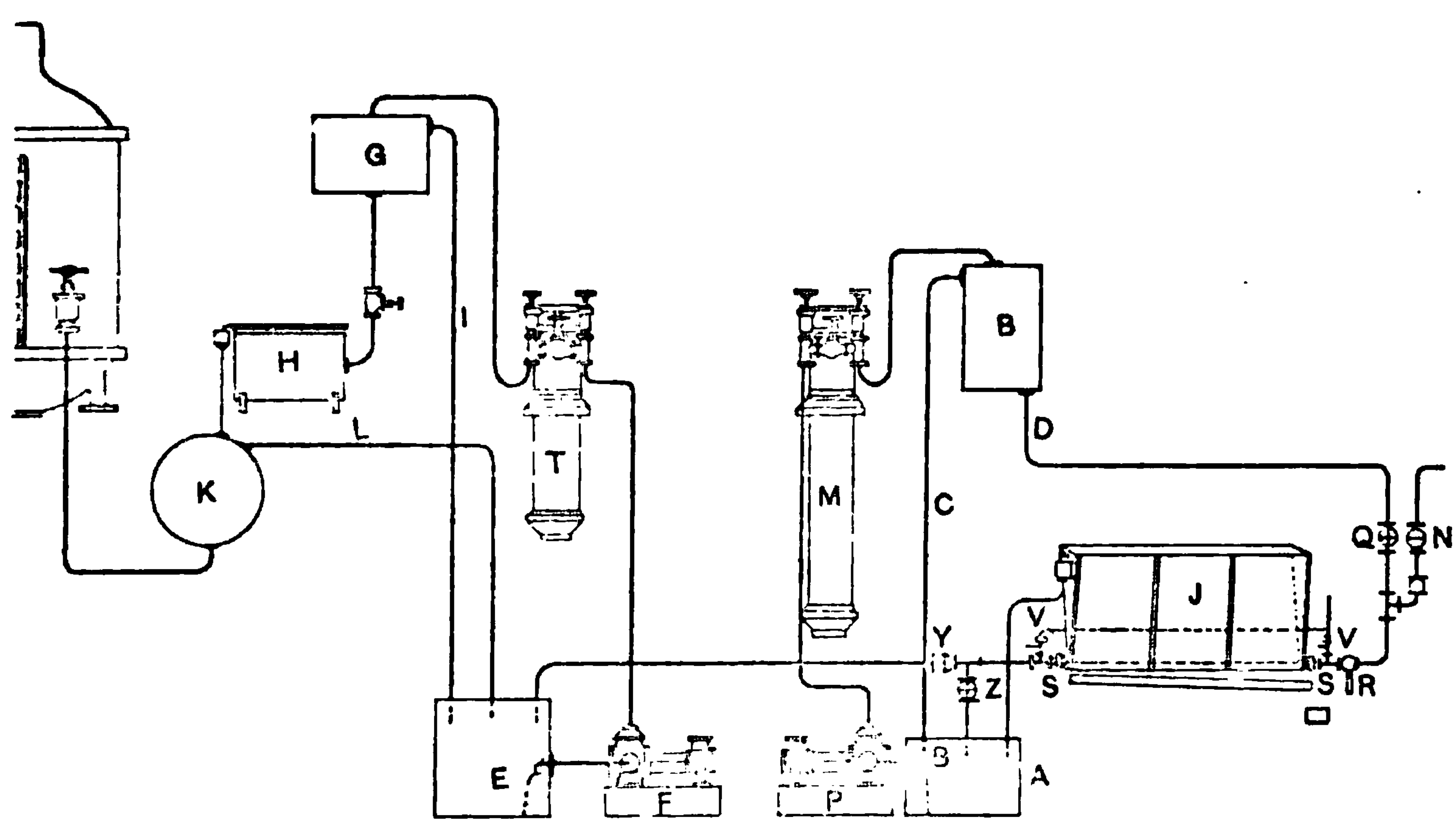

FIG. 174.—DUFAY'S Method of Curing After-products.

These juices become saturated with sugar and run into the reservoir, *A*. As long as they have not the desired density of 25° to 30° Bé., a pump, *P*, forces them through a reheater, *M*, the reservoir, *B*, the pipe, *D*, and the valve, *Q*. Under these conditions the juices become more and more charged with the drained sugar, the purity of which is about 90. When sufficiently concentrated, it is allowed to run off at *Y* into the reservoir, *E*, from which a pump, *F*, forces it through the reheater, *T*, the reservoir, *G*, and the PHILIPPE filter, *H*, and then into the receptacle, *K*, from whence it is drawn into the vacuum pan.

Another French process, which has attracted some attention, is that of BOUILLON. The after-product of "firsts" is grained in accordance with well-known methods, and the final product contains 8 per cent of water. The massecuite falls into seven mixers and is left to cool. In order to obtain the desired fluidity, molasses

previously heated to 75° C. is added, and after three days, when its temperature has fallen to 35° or 40° C., a pump forces it to the draining station. It is essential for success that this latter operation should not commence before the mass is at 40° C. There are six drainers, which consist of sheet-iron receptacles 1 meter in length, 0.7 meter in width, and 0.35 meter in height, with a capacity of about 2 hl. They may be made to revolve, and in their interior, at a few centimeters from the bottom, is a perforated wire cloth with rectangular openings 1 to 2 mm. in width. The bottom has a special opening for emptying. These drainers may be closed with covers worked by a hydraulic piston, and each cover may be connected with a compressed-air reservoir. The compressed air enters at a pressure of one kilo, and may be heated during its passage in calorizators, but this is not absolutely necessary.

When the operation is to commence, the hydraulic piston raises the cover; the drainer is then filled with second massecuite, the cover is placed in position, the joint is tightened, and the compressed-air valve is opened. The pressure exerted upon the surface gradually forces out the mother liquor or molasses. The length of this operation depends upon the viscosity, the temperature, and the size of the crystals of the massecuite, but as a general rule it lasts from 5 to 15 minutes. When air begins to escape at the bottom the operation is ended, the cover is removed, and the drainers are made to revolve. The mass thus drained falls into a hopper communicating with the carrier that deposits it in the crystallizators of "first molasses."

It is concluded that this method of working gives satisfactory results, only provided there is a certain homogeneity in the size of the crystals, and, further, the viscosity as low as possible. At first, difficulties were experienced in determining the most desirable limit of draining. The early experiments were with a suction device, but numerous difficulties arose, and the final conclusions were in favor of compressed air.

Usage of after-product sugar.—In the two preceding methods it was shown to what use the after-products may be put. In some countries this commodity is much sought after on the market, especially when the graining has been properly conducted. It is to be noted that, when this after-product sugar is made for exportation, the centrifugating is so arranged that it may have a refining yield of 70 to 80. Under these conditions the quantity of after-products of "seconds" is considerably decreased. On the other

hand, in countries where these sugars are not sold on the market, it is often customary to mix them with sugar, or first massecuites, especially when the crystals are about standard. Of late it has become customary to redissolve them in the juices, under which conditions the crystallization is better and the product is more readily sold.

According to BERKEFELD, it is more economical and profitable in the long run to melt up the after-products and add them to the second carbonatation juice, provided, however, that this sugar has a purity coefficient higher than the beet syrup. The purity of the juice under these circumstances would be raised, and the ultimate quantity of first-grade sugar extracted would be increased. For example, if a massecuite has a purity of 90 and gives 70 per cent of sugar, with 91 purity there would be obtained 73½ per cent of sugar. The influence of this increase is particularly evident when inferior beets are being worked, or when, in other words, the juices do not readily crystallize. Furthermore, it is claimed that the remelting of the after-products and their addition to the juices of second carbonatation economize labor and decrease the cost of manufacture.

According to ZSCHEYE, there is a limit at which the remelting of these sugars is no longer profitable. According to this authority, the best results are obtained with sugars that have a refining yield of 79 to 80 per cent. When it is intended to redissolve the sugars in the juices, there are advantages in pushing the swing-out operation as far as possible; but it would be a mistake to resort to steam curing to attain a better quality of sugar, as the purity of the resulting swing-out would also be higher. The sugar is dissolved either in the filtered first-carbonatation juice or in the syrup, the former offering advantages over the latter, for the reason that the solution is more readily accomplished, and, furthermore, a portion of the impurities may be separated through subsequent filtration.

LEHRKE [1] finds an advantage in dissolving the second and third sugars in the centrifugal itself when the molasses has been separated. The sugar is dissolved in water or hot juice, and the saccharine juice thus prepared is run through a filtering cloth to separate the particles in suspension. All this is accomplished without bringing the centrifugal to a stop, and at very little cost of labor.

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[1] D. Z. I., 26, 1105, 1901.

Attention is called to the importance of closely watching the working of the centrifugal, to make sure that the swing-out operation is entirely finished before the remelting commences. Special centrifugals can be used for this purpose, and will be described under the caption of Sugar Refining in Factory. A special pump forces these remelts into carbonatation tanks.

Care to be given to centrifugaling of after-products.—The swing-out operation of after-products should be conducted with great care, so as to obtain the greatest amount of sugar. The "firsts" and "second molasses" should be kept entirely separate; otherwise the time necessary for obtaining the final molasses would be increased. Great stress should be placed upon thorough cleanliness.

PART VII.

MANUFACTURE OF WHITE SUGAR.

CHAPTER I.

GRANULATED SUGAR.

General considerations.—The sugar obtained through centrifugating, as has been described in the foregoing, is not ready for consumption, as there still adheres to the surface of the crystals a syrup which gives the product an objectionable flavor and odor. The swing-out operation can be continued by the addition of a cleare, which curing would give a final white sugar. But refiners prefer to remelt the raw sugar, and subsequently to submit it to various manipulations and final crystallization. Some beet-sugar factories are built in order to manufacture every kind of refined sugar under the same conditions as in the refinery; but, as much more labor is needed to produce these refined products than for the raw sugar, this work is frequently continued after the beet-sugar campaign is ended.

When the manipulations in the factory have been conducted in accordance with the accepted scientific principles, it is possible to grain granulated or crystallized sugar sufficiently white and pure to enter into consumption without any further handling. When there is no market demand for such sugars, the curing proper is not resorted to, and the sugar is only partly freed from its adhering syrup. This slightly yellow raw sugar is sold directly to the refiner.

Remarks respecting graining.—When it is desired to manufacture perfectly white sugar, the syrup boiled in pan must be as pure as possible. It would be a mistake to draw in the after-products of a previous strike. If the growing crystals in pan during

the operation of graining were fed with such molasses, the layer of sugar that would be deposited upon the crystal already formed would carry with it a certain quantity of the after-product, which is of an almost microscopical volume, but yet is sufficient to impart some color to the final sugar. If after-products are introduced into the pan, it must not be done with the idea of increasing the size of the crystals, but for the purpose of rendering the mass more fluid towards the end of the strike.

The graining is begun under the regular conditions. The coefficient of supersaturation should be rather low and the nucleus of the strike comparatively small. The grain obtained should be of a size determined upon in advance, and it is essential that the size be kept down, for the larger crystals are not readily disposed of on the market. Upon general principles, it may be said that the lighter the syrup is, the harder and brighter will be the ultimate crystals. On the other hand, with thick syrups exceptional care must be given to the working of pan. Ample time should be allowed for completing the strike. When the operation is finished, it is supposed that the mass retains from 7 to 11 per cent of water. Of late, however, there appears to be a tendency in favor of leaving a comparatively high percentage of water. In fact, no tightening is thought necessary; for the increased yields obtained by this method do not compensate for the increased loss during the centrifugating necessary to remove the syrup adhering to the crystals.

Preparation of the massecuite.—For the preparation of crystallized sugar, the massecuite at first is worked in the centrifugal just as if raw sugar were the object in view. It is important not to allow it to cool, so that as much syrup as possible may be swung out. The after-product which has not been removed by centrifugal force is washed from the crystals by means of water, steam, or a supersaturated sugar solution known as a cleare. Care should be taken that as little of the crystals as possible be dissolved.

Centrifugals for granulated sugars.—Granulated sugars may be obtained in all centrifugals used for the swing-out of raw sugars, provided, however, that certain rules be followed. As a general thing, the best results are obtained by the use of special centrifugals when a given type of granulated sugar is the object in view. Upon general principles, preference is given to large-diameter centrifugals, as they require less labor and do not cool too rapidly. It is to be noted in regard to this cooling that in certain factories

the outer casing of centrifugals are surrounded with boards, or some non-conductor.

The spindle, drum, etc., of these centrifugals have no special characteristics. The portions for the distribution of the cleares used for curing the sugar, and the provisions made for the exit flow of the various after-products, will be described under the next headings.

Separating the swing-outs.—During the washing, an after-product of a higher purity than that of the mother liquor is obtained. In theory all the last parts of the swing-outs should be of the highest purity, so that the cured sugar may be absolutely pure It necessarily follows that the last cleare used should permit the realization of the object in view. In practice, the swing-outs under consideration have a purity a fraction higher than that of the syrups leaving the multiple effects. If these separated rich after-products are mixed with the lower-grade syrups, the final labor needed for their exhaustion will be increased. Hence efforts have been made to classify these after-products. The higher grades may be readily returned to pan during the graining of firsts, or to any other preceding phase of the manufacturing process. In some sugar factories they are again used as cleares. As early as 1852 PERIER [1] recommended this swing-out classification.

The simplest device for after-product separation consists in placing an oscillating plate under the exit pipe of the after-products, and over two separated gutters corresponding to separate tanks. As soon as the swing-out syrup seems to be much lighter in color, the direction of the plate is changed, and the higher-quality product is sent into the other gutter. For the separation of these syrups, it is essential that the centrifugating of each load last long enough for the green syrup to be well out of the drum before the cleare used for curing is introduced; and for the same reason the cleare should be thoroughly removed before a new load is introduced into the drum of the apparatus. The separation of the after-product is consequently more effectually accomplished in large centrifugals, which spin for a longer time than the smaller appliances. It is self-evident that many more centrifugals are needed for manufacturing white crystallized sugar than are required for brown sugar.

NAUDET has proposed an arrangement that is almost automatic in its working. At the beginning of the centrifugaling a

[1] Z., 2, 109, 1852.

certain quantity of syrup from the previous operation is still adhering to the drum of the apparatus. The first portion of the after-product that runs off passes by the exit pipe and the distributing trough, *A* (Fig. 175), and flows into *II*. At first the green syrup carries with it the high-grade after-product from the preceding operation. Its flow is comparatively slow at that moment, but little by little the volume becomes greater, and at the same time its purity decreases, as all the rich after-product has been carried away. At that instant the greater weight of the molasses has displaced the

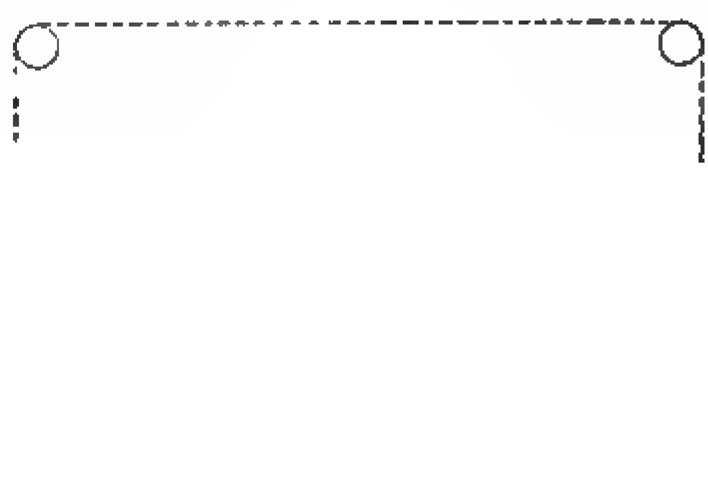

FIG. 175.—NAUDET After-product Classifier.

centre of gravity of the plate, causing it to revolve and to distribute the after-product into *III*. The exit flow decreases again when the curing commences, the plate takes its former position, and the rich after-product, driving before it some of the inferior molasses with which it mixes, is again distributed into *II*. When the swing-out is no longer mixed with the lower-grade molasses, *A* is raised to *A′*, and it flows into the gutter, *I*.

ABRAHAM[1] has an automatic classifier that has met with some favor. It consists of a moving but balanced receptacle, having at its bottom a series of holes, which allows the after-product to escape freely as long as its volume does not exceed given limits and it is not too viscous. By simply regulating the counterpoises of the plates that guide the after-products into the reservoir, it becomes possible to classify these swing-outs according to their viscosity.

However, in most factories attempting to classify the after-products according to the variation in the purity, there is never more than five or six units difference between the purity of the richest and poorest. This does not seem satisfactory when one

[1] C., 11, 498, 1903.

considers that the green molasses from a good massecuite has a quotient of 74 and the swing-outs from the curing are only 80, while a certain portion of the same certainly attains a purity of 95. This is explained by the fact, as previously pointed out, that there is always a certain quantity of syrup still adhering to the inside of the casing of the centrifugal, which, even after considerable spinning, cannot be eliminated, owing to its viscosity. LUBINSKI and KRAJEWSKI[1] have attempted to overcome this difficulty by introducing steam between the centrifugal and its casing after the first stage of the swing-out operation is terminated, with the result that there is a thorough removal of all the green syrups.

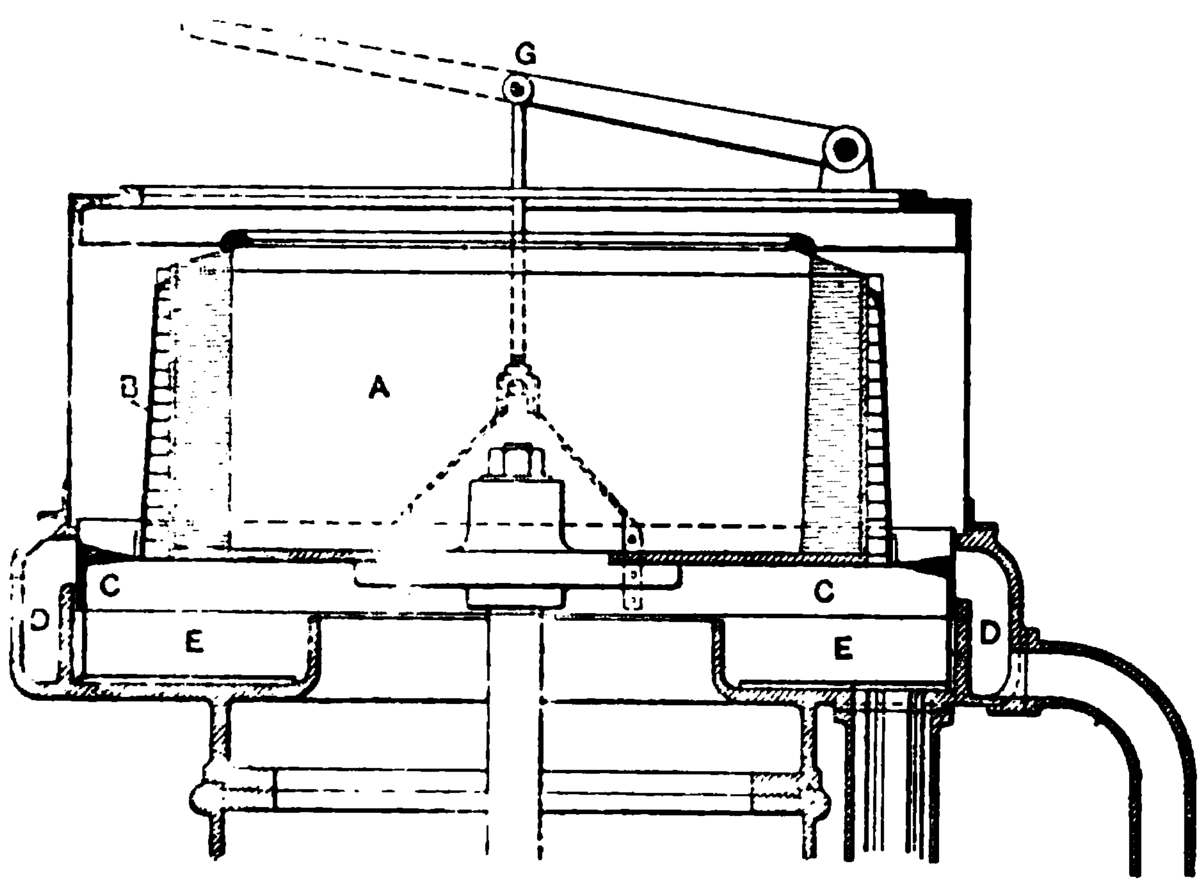

FIG. 176.—SUDENBURG'S Works After-product Classifier.

There necessarily follows a dilution, which means more water to be evaporated when these after-products are again grained.

A very interesting arrangement for the classification of after-products, which was in a measure a starting point for numerous other devices, is MALANDER'S centrifugal, from which, it may be said, derives the device of the SUDENBURG'S works. The latter (Fig. 176) consists of a drum, A, surrounded by a conical casing that revolves with it. The after-product projected against it, under the influence of the centrifugal force applied upon an inc ined plane, is forced downward and flows very rapidly along the sides, and none of the green molasses remains adhering to it. At the lower part of B the after-product escapes rapidly, being projected against a ring, C, and then run off through the gutter, E. As soon as all appears to be

[1] N. Z., 40, 108, 1893.

ready, the second operation, or actual curing, commences. The ring, C, is lowered by means of the lever, G, and the rich after-product is thrown out into D. There is thus no mixing with the green syrups.

The KESSLER arrangement is shown in Fig. 177. It is provided with an exterior envelope, arranged very like a Venetian blind; in Fig. 178 is another section, showing the position of the blinds when closed at top and bottom. Between the outer iron casing of the centrifugal, a, and the drum, b, are placed the portions of the blinds under consideration. They consist of slightly conical rings, c.

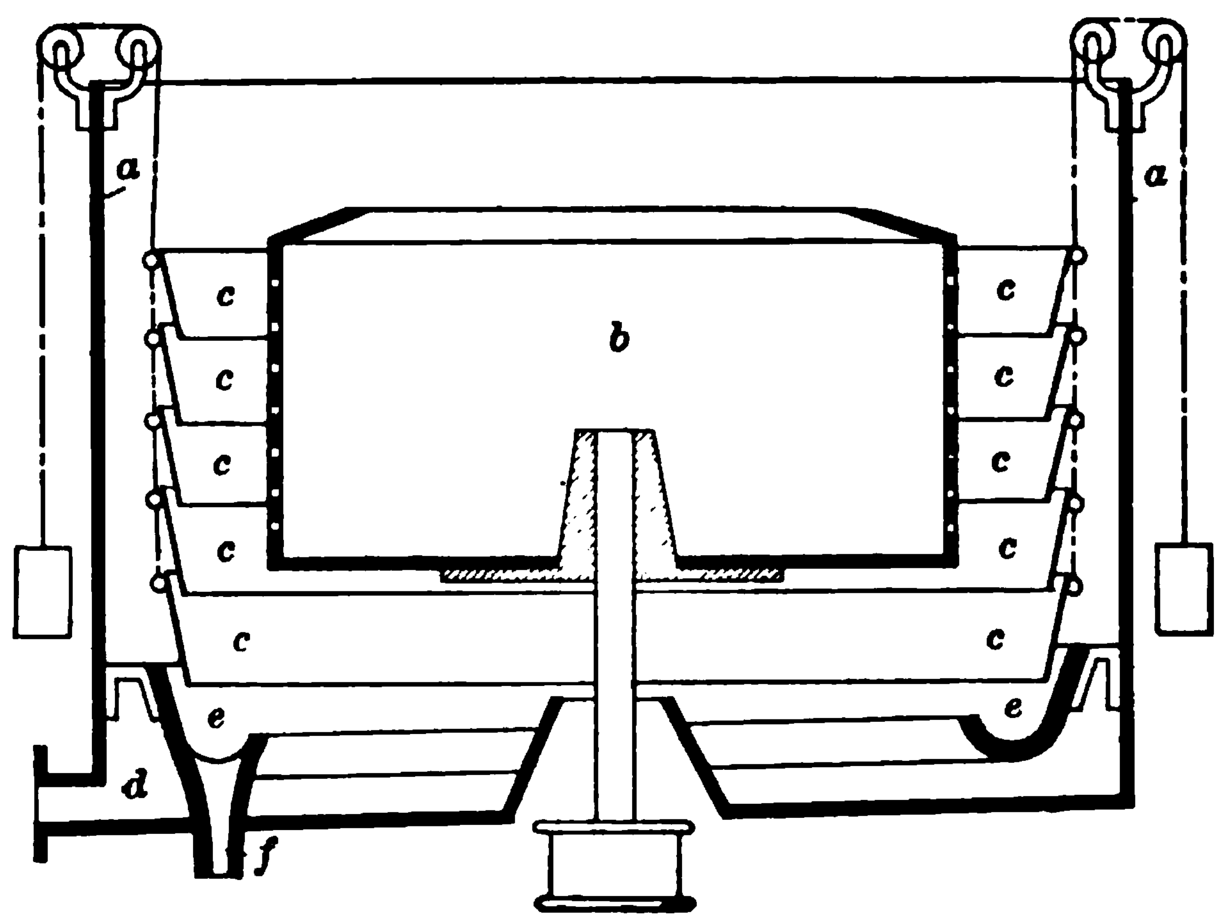

FIG. 177.—KESSLER Classifier (Open).

Any portion of the separated after-product that is projected against c soon finds its way to the collecting trough, e, at the bottom, from which it escapes by the orifice, f. When the blinds have the position shown on Fig. 178, the after-products run off through d. The blinds may be raised or lowered by simply displacing weights acting as counterpoises.

Numerous experiments have been made to introduce the continuous centrifugals in factories manufacturing white sugar, especially the type of SZCZENIOWSKI and PIONTKOWSKI that was fully described in another chapter. However, all attempts in this direction have not proved successful, for the reason that certain essentials in the manufacture of granulated sugar are destroyed by a continuous centrifugal; for example, as previously mentioned, these sugars are not homogeneous, which alone would prohibit

their use, and the crystals are frequently broken, which would be an additional objection.

Use of cleares.—As early as 1851 GWYNE[1] suggested that centrifugals be used for the maufacture of granulated sugar. He proposed that water or after-products be used as cleares for the curing. When a saturated solution of pure sugar is used as a cleare, no sugar is dissolved, and thus all the sugar crystallized is obtained in the form of crystals. But as a certain amount of sugar is dissolved

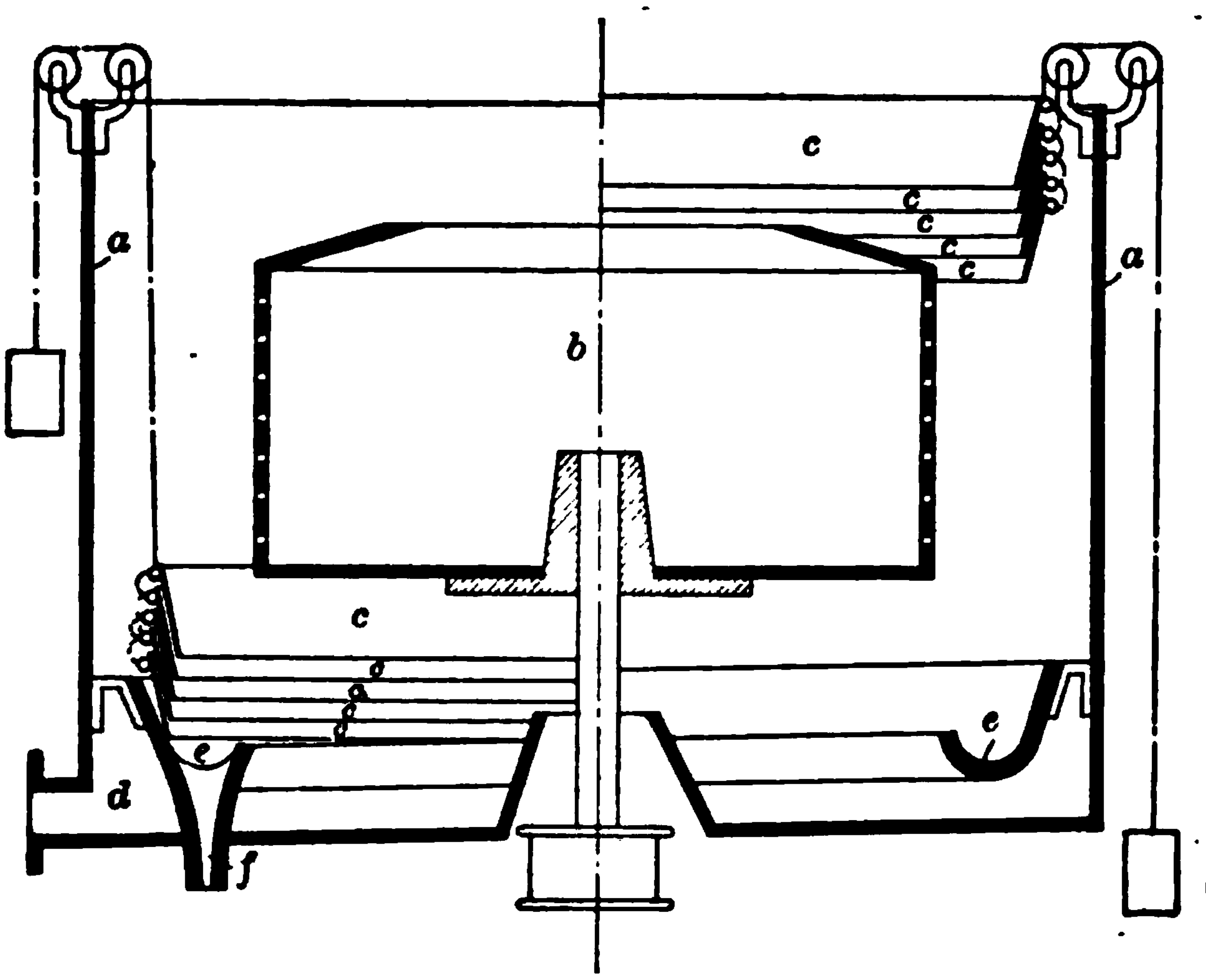

FIG. 178.—KESSLER Classifier (Closed).

for the preparation of the cleare, and as these cleares become mixed with the impure after-products during the swing-out, they can no longer be used for their original purpose, which lessens the actual yield of crystallized sugar.

As has been pointed out, the cleare of best quality consists of a pure-sugar solution, sufficiently dense (say 35° to 38° Bé.) so as not to dissolve the sugar crystals with which it comes in contact while in the drum of the centrifugal. If the cleares are used alone, that is to say, if steam and other adjuncts are not employed, their purity plays an important rôle, especially that portion which is last to wash the sugar crystals, as, if not pure, it leaves in the sugar an objectionable taste. The best way of preparing a cleare is to dissolve pure sugar in water, using for the purpose sugar having a

[1] Z., 1, 543, 1851.

low market quotation, owing to the size of its crystals, irregular aspect, etc.

No special rule can be given as to the quantity of cleare that is desirable for curing, as it depends upon the degree of tightening of the massecuite, the size of the crystals, and the quality desired for the final sugar. The amount should be as small as is practicable, as to prevent to raise the purity of the after-products and increase their volume. Various methods have been adopted for the introduction of the cleare upon the massecuite. It may be sprayed on by means of a tube, or simply thrown in the centrifugals by means of small cups of a known capacity. The question of the temperature at the cleare has been much discussed. ANSEL and BEAUDET[1] recommend that it have the same temperature as the massecuite.

For regulating the entrance of the cleares into the centrifugals, HRUSKA[2] used an injector. A small pipe runs from the pipe holding the compressed gas to the upper part of the receptacle holding the cleare, so that it has the same pressure as that of the compressed gas. This pressure, in all the variations arising, is regulated by suitable valves, and the cleare is introduced upon the sugar under such conditions as circumstances may demand. In order to ascertain with considerable accuracy the volume of cleares used during sugar purging in centrifugals, WEINMANN and LANGE[3] proposed to place over each centrifugal a small reservoir with an overflow, and an entrance and exit valve for the liquor, with a graduated level-indicator.

It may happen that, notwithstanding the care given to the curing, the granulated sugar left on the drum of the centrifugal will still be slightly colored, and, with the view of removing this color, a final cleare is used, to which is added marine blue 0.0. in sufficient quantity to cover the yellow tinge of the sugar, making it appear whiter. It is important in such practices, which are generally in vogue in the United States, not to use the product in excess, or a blue-tinted sugar, which is even more objectionable to the eye than the yellow, will result. The marine blue is the only substance allowed by the countries of Continental Europe for this purpose.

Very naturally, purchasers of sugar continually protest against the use of coloring substances to give sugar a specified shade. Some chemists have declared that the marine blues are poisons; but, if

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[1] Bull. Asso., 8, 155, 1890. [2] Z., 50, 842, 1900. [3] Z., 53, 234, 1903.

such were the case, the entire Russian nation would long since have been killed, for no beet-sugar-manufacturing country pushes the use of that chemical to the extent that they do. BAUMERT swallowed half an ounce of the marine blue at one time and suffered no inconvencience, which proves how very inoffensive the small quantity of the substance under consideration must be. It is interesting to note that blued sugars, after a period of keeping, have a grayish tint, especially when left in a damp place for a time. HERZFELD[1] claims that this change in color is due to an inner transformation of the blue with formation of a ferrous sulphid.

Drost and Schulz process.—Thirty years ago MARGUERITTE[2] proposed to use the multiple-effect syrups, concentrated to 35° Bé., as cleares for curing sugar. This idea was taken up and put into practice, with certain improvements, by DROST and SCHULZ.[3] The massecuite in the centrifugal is freed as far as possible of its green syrup during the swing-out in the centrifugal. The outer casing of the apparatus is then moderately heated to facilitate the flow of the after-product; and when this has escaped into a special gutter, the curing commences with a syrup of 66° Brix as it leaves the multiple effect. About 10 per cent of cleare is used. The sugar then has a polarization varying from 99.2° to 99.6°. As it still has a slightly yellow appearance, dry steam is introduced between the drum and the outer casing. The curing with steam means the solution of from 2 to 3 per cent of crystals; but the purity of the rich after-product allows it to be introduced into pan during the graining of firsts. It is generally admitted that, by the process under consideration, a massecuite containing 86 per cent of sugar and having a purity of 91.5 will yield from 63 to 64 per cent of sugar polarizing 99.7°. The green syrups, or first swing-outs, have a purity of 71. The sugar obtained is sifted. Some of the leading authorities hold that this procedure does not possess the advantages of economy claimed for it.

Swing-outs used as cleares.—Impure cleares can be used for curing sugars, provided the first curing is followed by a second, which consists either of a steaming, or working with water, or a pure-sugar solution. After-products diluted to 37° Bé. from firsts may be used, and in this case there need be no fear of dissolving the sugar crystals.

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[1] Z., 51, 1, 1901.

[2] J. d. f. d. s., 14, 26, 1873.

[3] Oe.-U. Z., 19, 314, 1890, and Z., 41, 546, 1891.

Water as cleare.—Instead of preparing the cleares in advance, they may be made in the drum of the centrifugal by injecting water. This washes off the green syrup adhering to the surface of the sugar crystals, and then partly dissolves the sugar itself, forming more or less concentrated sugar solution, which cures all the sugar with which it subsequently comes in contact. This water-curing is done by the fine spraying of all the sugar on the drum, along the entire inside surface, from top to bottom.

The injectors generally used for this purpose are the KOERTING pulverizators (Fig. 179). The height of the apparatus may be regu-

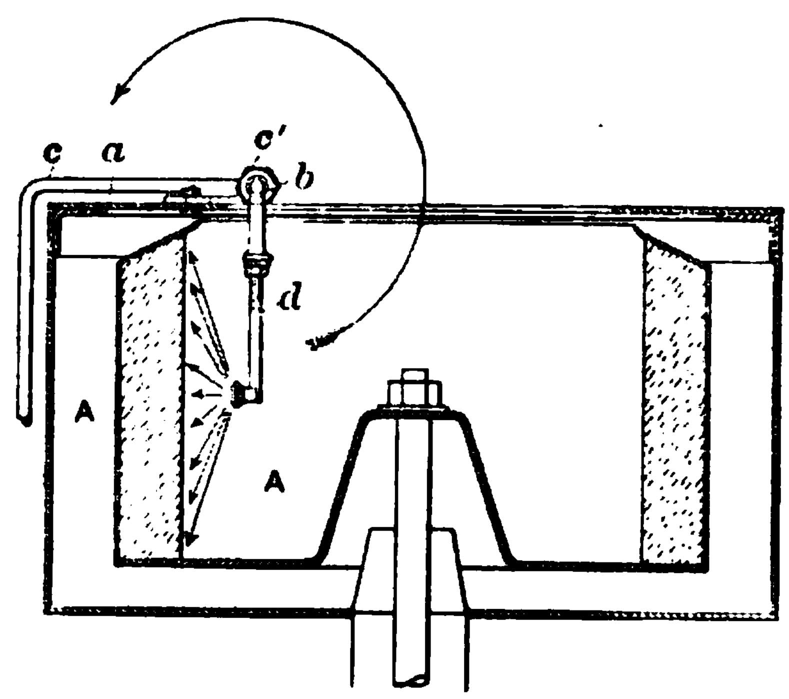

FIG. 179.—KOERTING Water-sprayer.

lated by means of the threaded portion of *d*. During the introduction of the load of massecuite, the rod is thrown back and outside of the centrifugal, revolving around *b*, and being held tight by means of a nut, *c′*. Water is introduced through *c*, resting upon the top exterior casing, *a*, of the apparatus. When the green syrup has been swung out, the pulverizator is placed in the interior of the drum, *A*. By putting it in this position, a small valve in *b* is opened, and the curing continues just so long as *d* remains in the position shown in the drawing, and ceases when it is removed from inside the drum. This curing lasts one or several minutes, depending upon the quality and nature of the massecuite being treated, and also upon the capacity of the sprayer used. The efficiency may be regulated by tightening or loosening a small screw in the interior of the pulverizator.

The WEINMANN and LANGEN [1] automatic appliance for curing sugar has also met with some favor among manufacturers. It consists of a telescopic tube connecting with the water or cleare pipe,

[1] Oe.-U. Z., 32, 763, 1903.

and at its extremity is a pulverizator. As soon as the water-cock is opened, the telescopic tube leaves its case, and remains in the extended position in the interior of the drum as long as the curing lasts, returning to its original position, under the influence of a counterpoise, when all water or cleare pressure ceases, the cock being closed. The pulverization of the water may be obtained either by the pressure from an upper reservoir or through the action of compressed air or steam.

The success of the curing largely depends upon the regularity of the spraying. If in excess at any spot, the results will be dis, appointing. There will be more sugar dissolved than is needed- as at this spot the sugar will be almost washed out when the other portions have still a yellow hue. The spray must be equally separated over the entire surface of the sugar. As a matter of fact, this is never the case with these pulverizators, as the area of sugar covered by the spray is a circle. On top and bottom of the centrifugal the sugar passing before the appliance will be in this area only a minute fraction of the time needed for any crystal of sugar to cross this area in the middle of the height corresponding to the diameter of this field. A tube with a slit would theoretically give better results, but is subject to irregularities and deformations. Instead of this, it is resorted to an increase of the number of sprays, thus lessening the evil. When several pulverizators are simultaneously used inside of the same drum of a centrifugal, the spray of each must be kept entirely separate; otherwise there would be an excessive washing at the point of interference of their area. The period that the water curing lasts depends upon the masse-cuite being handled. Several experiments must be made before deciding within what limits the best results are obtained for a given strike, but, when once determined, the time remains about the same for all the loads of a same strike.

Curing with steam.—Steam as a cleare was first proposed by Farinaux.[1] The only difference between the action of steam and water upon the sugar crystals of a massecuite is, that with the former there is more sugar dissolved. The steam will fluidify the green syrup adhering to the surface of the mass of crystals; it condenses and it dissolves some sugar, forming an excellent cleare, very rapid in its action, but, in most cases, not economical.

There are several methods of curing with steam. The use of a

[1] Z., 3, 304, 1853.

rubber pipe, or any other form of movable pipe with suitable perforations, for bringing steam in contact with the load contained in the drum of the centrifugal, is now almost obsolete. It was found that this crude method of curing gave very irregular results. The more modern method demands the use of special centrifugals. Near at hand is a small receptacle, in which the steam is expanded to a very low pressure, and in which is retained the water carried forward by the steam. This expanded steam is brought by means of a pipe to the cover of the centrifugal, and is thus made to act from the centre of the drum.

The steam injector of Deutsch[1] consists of a water separator connected with a purging device and of several tubular portions, adjusted one at the end of the other, and having a cock for separating the steam, which becomes drier. There are several attachments connected with the apparatus, such as an angular valve for regulating the entrance of the steam into the centrifugal. The injector, properly speaking, is attached to the cover of the turbines and connected with an angular valve by means of a rubber tube. All the tubular portions, from the valve to where the water is separated, are slanting, so as to allow the water that condenses when the valve is closed to flow back into the separator.

In the Fesca centrifugal the steam is injected with air, which, at a comparatively low temperature, causes a sort of mist, very well suited for the curing in view. Koerting draws water into a large receptacle by means of a steam injector, and the resulting moist steam draws in air when passing through a second injector. A cloudy mist is thus formed, the temperature of which may be regulated to suit the work being done. The duration of steam curing must be fixed to suit each special case, as is determined by a series of experiments. That there may be no difficulty in removing the sugar from the sides of the drum, the action of the steam is allowed to continue as long as the spinning lasts.

It frequently happens with steam curing that certain difficulties arise owing to the escape of steam into the centrifugal room, causing almost everything to become moist, especially metallic surfaces and the belting. To overcome this difficulty, it is proposed to close all the centrifugals used for steam curing with a suitable cover, having a rather large diameter pipe which helps to carry off the excess of steam. The Legentil[2] covers consist of a series of

[1] S. B., June, 1902.

[2] La. S. B., 11, 35, 1882.

segments sliding one over the other like a fan. To overcome this difficulty of escaping steam, DEVRIES [1] has arranged, along the upper border of the drum, a series of flaps which throws the steam against the outer casing of the centrifugal, from which it escapes through special chimney-like outlets. The advantage of this mode is, that the steam coming in contact with the sides will to a certain extent condense, and this water of condensation, mixing with the after-products, gives them considerable fluidity, thus permitting their rapid escape.

What is known as the Russian mode of curing was invented by CHERSTOPEROFF.[2] The steam is introduced between the outer casing of the centrifugal and its drum, and a portion of it passing through the massecuite does the curing. The process in question is not generally used for the production of granulated sugar, for it is too slow; but it has been considerably used for centrifugating after-products. Precaution should be taken, when introducing the steam not to bring it into immediate contact with the drum of the centrifugal, for the reason that the water carried forward by the steam will be projected against those places and diminish the sugar yield. The best results are obtained by directing the steam in any direction desired by some simple device, through which it may be uniformly distributed between the drum and its metallic covering.

Superheated steam and other gases.—All the processes for curing which have been mentioned possess one main objectionable feature, namely, the solution of considerable sugar, or the escape of sugar of the prepared cleare into the after-products. It has been proposed to use all sorts of hot gases to reheat the green syrup adhering to the crystals and render it sufficiently fluid to hasten its escape. To superheated steam special attention has been given, and its use has been most varied, notwithstanding the fears at first entertained that, owing to its high temperature, it would decompose the sugar.

In the BAKER [3] method, superheated steam is used as a cleare at 0.4 atmospheric pressure; this is at a temperature of 108° C., which is subsequently raised to 200° C. before being introduced into the centrifugal. This steam can abandon all its heat up to 100° C. and heat the centrifugal and the massecuite without there being any condensation, the principal object in view being to bring about just sufficient condensation to work the crystals and to heat the product through its entire mass without excess of steam.

[1] Z., 53, 528. 1903. [2] Z., 22, 515, 1872. [3] S. I., 51, 396, 1898.

During the steam injection ultramarine blue is used, the quantity needed being small, about 0.0015 per cent. The superheated steam is prepared in a special apparatus, for which about 250 kilos of coal are required for 40 tons of sugar. When the steam is at the desired temperature the centrifugal is filled with hot massecuite, and during this interval the drum is left open. The steam is not introduced until the green syrup ceases running, when the apparatus is closed and the superheated steam run through the product. The time required for the operation is governed by an hour-glass filled with sand; when it is empty the steam is cut off. The entire working by this method depends upon the grade of sugar it is desired to obtain. It is claimed that the yield varies from 96 to 98 per cent of the theoretical quantity, depending upon the size of the crystals being worked.

Hot air for curing was recommended by BUREAU.[1] The mother liquor of the massecuite, during its working in the centrifugal, is warmed by the use of hot air without dissolving any sugar, permitting it to flow rapidly from the sugar crystals. Furthermore, it is claimed that the sugar thus obtained is dry and need not be worked in a granulator. While the process received the approbation of numerous experts, it does not appear to have been introduced in many plants.

Losses.—By all methods of curing, important direct sugar losses occur. This is made evident by the difference in sugar yields obtained. The following differences are supposed to be the outcome of actual experiments in centrifulgaling one hectoliter of massecuite:[2]

Curing with steam alone.........	74 kilos of sugar with refining yield of 98.75
Curing with hot cleare at 70° C., 35° Bé. and steam...........	73 kilos of sugar with refining yield of 99
Curing with cold cleare 23° Bé. and steam..................	72 kilos of sugar with refining yield of 99.1
Curing cold water and steam......	67 kilos of sugar with refining yield of 99.5

The SEYFERT[3] process was supposed to do away with these losses by using, as a substitute for water, cleare, and steam, another liquid not containing sugar, and not dissolving sugar during the curing. As it may be applied to any massecuite, a brief description may be given here. In this process, paraffin oils obtained from coal-tar

[1] S. I., 29, 646, 1887.
[2] La. S. B., 20, 205, 1892.
[3] La. S. B., 17, 548, 1889.

distillation are used. The first part of the swing-out operation is conducted as usual; the centrifugal is then closed and a jet of paraffin oil is sprayed upon the mass, passing readily through the sugar crystals and cleaning them. When the sugar is very viscous, the operation ends with the use of a little water. The paraffin oil readily separates from the syrup. The yield of white sugar is satisfactory, but it has a slight odor of petroleum, which, however, disappears entirely when the sugars undergo remelting in the refineries. This process has had comparatively few advocates, yet certain German beet-sugar factories gave it an extended trial. The Federal Refining Company introduced a method not unlike it, but, instead of paraffin, they used liquids extracted from numerous oils and resinous substances. It was claimed that there was not only a curing of the sugar, but that the substances in question had an important action upon the non-sugar contained in the after-products.

Steffen washing or curing.—Another method for the manufacture of white crystallized sugar from the granulated mass is the washing of the massecuite. This process is simply an improvement on the SCHUEZENBACH method mentioned under another caption. The idea of this method was first thoroughly examined from a technical standpoint by ANTHON,[1] and assumed a practical shape when modified by STEFFEN. When the graining is completed the massecuite is cooled in suitable crystallizors at 40° to 50° C., and then diluted to a point at which the mother liquor becomes only partly supersaturated. In no case should it contain fine crystals or crystal powder, but a good and regular grain.

The draining boxes consist of small flat-bottomed cars having each a capacity of 17 hl. Near the bottom is a metallic cloth, underneath which is a pipe communicating with an air-exhausting appliance. By producing a vacuum the green syrup is drawn from the surface of the crystals of the massecuite. The floor of the building where this operation is accomplished is crossed by rails, turntables, etc., permitting all the small cars to be successively brought into position to receive cleares of different purity. Each passage of cleare takes place simultaneously in all the cars containing portions of the same strike, and each car receives the same quantity of cleare.

As soon as the green syrup has nearly all run off, another syrup of a higher purity is poured upon the surface of the massecuite,

[1] Z., 16, 616, 1868.

and is also subsequently drawn off from the bottom; this operation is repeated many times with syrups of increasing purity. While the first cleares are from a previous operation, the last of the series is simply a solution of pure sugar. Sometimes a special cleare is prepared, or, again, water is poured upon the washing reservoirs, and becomes saturated by the solution of the crystals in the tank itself. Special care should be taken that the separation of the after-products from these washings be properly effected.

To prevent the mixing of the several cleares, it becomes necessary that they pass through the different layers of sugar at the same velocity. New cleares are not run in the cars until the previous syrup is well separated from the crystals of all the receptacles. The first after-product running off has a purity of about 70, and is not again used for this washing process; the second after-product is used for the first washing of the massecuite that follows, and so on. For the keeping and separation of the syrups, reservoirs with partitions or ordinary tanks are used, in which the syrup that first runs off in a supersaturated condition may be diluted with water to the desired concentration.

In a French factory visited by the writer, the raw sugar is successively submitted to the action of 32 cleares, each one in the proportion of 7 per cent of the sugar to be cleared. After the passage of the ninth or the tenth, the cars and their contents are submitted to the action of the vacuum of 8 to 12 cm. of mercury. One hundred kilos of sugar polarizing 95.8°, containing 1.28 per cent of water and 1.4 per cent of ashes, will yield 89.84 per cent of crystallized sugar polarizing 99.85° and 10.16 per cent of after-product having a purity of 68.6. After the thirty-second curing, there is passed through the sugar from 40 to 50 per cent of pure cleare, and the centrifugating begins. The compositions of the different cleares used are shown in the table on page 415.

As there are certain variations of temperature in the rooms where this sugar washing is done, it is not sufficient merely to prescribe a given concentration of the cleare to be used, but the density should correspond to the ambient temperature, so that the syrup may be in a constant state of saturation, and not at one time supersaturated and at another barely saturated. According to MITTELSTAEDT,[1] every precaution should be taken to prevent the temperature falling below 20° C., otherwise the syrups become

[1] D. Z. I., 18, 371, 1893.

too viscous and small crystals may form. Heated rooms during the cold weather are certainly very advantageous, and, all facts considered, are a money-saving and practical means of overcoming an otherwise very serious difficulty. From the same standpoint all supersaturation of the after-product used in washing exerts an objectionable action, while, on the other hand, the non-saturated after-product used for the same purpose will wash the crystals more rapidly, but will dissolve sugar and consequently decrease the final yields.

COMPOSITION OF 32 CLEARES USED IN A FRENCH FACTORY.

No. of cleare.	Brix.	Purity.	No. of cleare.	Brix.	Purity.
1	78°.3	69.7	17	71°.9	87.3
2	77°.9	70.8	18	71°.5	88.4
3	77°.5	71.9	19	71°.1	89.5
4	77°.1	73.0	20	70°.7	90.6
5	76°.7	74.1	21	70°.3	91.7
6	76°.3	75.2	22	69°.9	92.8
7	75°.9	76.3	23	69°.5	93.9
8	75°.5	77.4	24	69°.1	95.0
9	75°.1	78.5	25	68°.6	96.0
10	74°.7	79.6	26	68°.2	97.1
11	74°.3	80.7	27	67°.7	97.8
12	73°.9	81.8	28	67°.4	98.3
13	73°.5	82.9	29	67°.0	98.8
14	73°.1	84.0	30	66°.8	99.3
15	72°.7	85.1	31	66°.5	99.7
16	72°.3	86.2	32	66°.4	99.9

For circulating about 40 cleares, approximately 20 hours are needed. It is only when the massecuite contains strongly supersaturated syrup that there is an advantage in using for the first washing a cleare consisting of a non-saturated after-product, which forms a saturated solution by the mixing with the supersaturated syrup, and the washing is consequently hastened without any sugar being actually dissolved. It is advisable to work the massecuite in the crystallizators so that the mother liquor will ultimately become a saturated solution. The yield in white crystals is greater by the washing method than it is by the regular swing-out of massecuite in centrifugals, for the reason that a green syrup of a lower purity is separated. This result is, however, attained only at the cost of considerably more time.

According to LIPPMANN,[1] a considerable error is made in estimating the yields obtained by the STEFFEN process. The weight

[1] Z., 40, 580, 1890.

left after the deduction of the water, as determined by analysis, is estimated as the white sugar obtained, when in reality it is not water that adheres to the crystals, but a layer of more or less concentrated cleare. Consequently a very much greater weight should be deducted.

According to CLAASSEN, another disadvantage of working by this method is, that the after-products are used for too long a time before they are entirely eliminated as a residuum from the extracting process taken as a whole, and the ultimate change in their composition and its influence must be considered. In all cases the greatest care should be taken to exclude all conditions that may cause sugar inversion. The most important essentials in superior sugar extraction are cleanliness and the maintenance of the requisite alkalinity. Not lime, but a solution of caustic soda, should be used for the latter purpose. If, however, a marked inversion of the after-product occurs, the only practical way to overcome the difficulty is by thoroughly cleaning all the compartments of the washing tanks and recommencing the operation.

AULARD[1] recommends the STEFFEN washing process in the refinery, for the reason that all crystallizing tanks are done away with, leaving a residuary molasses of 54 to 55 purity. It is possible, however, to attain the same result with centrifugals when there are a sufficient number of crystallizators in motion to handle the after-products. One of the most objectionable features in connection with this process is the original cost of the plant. The buildings must be unusually large, and great judgment is needed to conduct the management upon truly scientific principles. The number of centrifugals is necessarily less than for the standard methods. The sugar obtained by this process is not entirely dry, and if it is to be sold as granulated it must be dried. It is first centrifugated, during which operation a large portion of the adhering cleare is removed, and is then run through a granulator like sugar that has been water or cleare cured.

Dryers and granulators.—The subsequent working of these sugars is governed by the market demand. The crystallized and granulated sugars should be taken from the centrifugal drum when still hot and moist, so that the crystals will not all stick together and form lumps. When crystallized sugar is prepared by steam washing, a special installation for the drying is unnecessary, as it

[1] Fourth Congress, 2, 111, 1902.

dries completely while passing to the sifting apparatus. Sugars that are washed with water or cleares should be dried in special revolving drums or granulators. The object of a granulator is to eliminate all water adhering to the crystals; furthermore, during the rotary motion of these appliances, the crystals have their edges rounded and will subsequently be more readily dissolved.

The manufacture of granulated sugar, properly speaking, goes back only about 40 years. There are numerous types of granulators. Those used in the United States, such as the HERSEY, need not be described, as they are well known to the American sugar manufacturers. In Continental Europe the LANGEN and HUNDHAUSEN appliance has had a certain vogue. It consists of a large sheet-iron cylinder, having a diameter of from 1.50 to 2 meters and a length of from 5 to 7 meters, which revolves around its axis upon suitable trolleys at a velocity of 5 revolutions per minute. The axis is nearly horizontal. The sugar to be dried is introduced at the highest end and carried upwards by a series of sheet-iron agitators, the directions of which are those of the generatrices of the cylinder. When at the top, the sugar falls from the agitators upon another cylinder concentric to the first, but steam-heated. At the entrance the liberated moisture is drawn off by means of a ventilator, which also removes from the other end the sugar dust formed by the friction of the dry sugar, and forces it into an apparatus known as a cyclone, where it can deposit, owing to the retarding effect produced upon the air current.

In order to greatly decrease the dust, SELWIG and LANGE do away with the interior cylinder and dry the sugar by means of a hot-air current forced against it just when leaving the granulator. The small amount of sugar dust formed is deposited at the other extremity of the dryer. The HENNIGE granulator consists of a vertical cylinder, about 10 meters high, in whose interior revolves an axis holding a series of horizontal disks. Between each of these there is a circular hopper which collects all that falls in order to bring it upon the disk beneath. The sugar is introduced on top, and, under the influence of the centrifugal force, falls successively from disk to disk and is dried by a rising hot-air current.

The BENDEL granulator also consists of a vertical cylinder, which is funnel-shaped at the top and bottom. At the top is a distributor consisting of a vibrating disk. The sugar, after being received in the conical hopper, falls like a shower the entire length of the cylinder without touching its sides. Hot or cold air, as the

case may be, is forced in from the bottom by means of small injectors. A special register allows the sugar, but not the air, to escape from the bottom of the apparatus. To prevent the crushing which necessarily occurs in most granulators, numerous devices have been proposed; but this difficulty is not considered as such by the consumer, as the side and edge crushing appears to be one of the characteristic features of the granulated product.

The PAATZ [1] dryer consists of linen carriers which work alternately in opposite directions, hot air circulating from one end to the other. Dryers in which there is a vacuum have also been proposed. It was claimed that desiccation would thus be much more rapid, but the difficulty arising was the entrance and exit of the sugar in these mediums where low tension is maintained. The GLASER [2] granulator is one of these vacuum appliances. It has an upper drawer, the opening for which exactly corresponds to the lower opening of the filling hopper. The drawer is arranged so that when full of sugar it will completely close the entrance to the hopper and thus exclude air. The same arrangement exists at the bottom, when the sugar is removed from the dryer.

Sugar sifting.—When sugar is intended for direct consumption it is essential that its appearance be more or less regular, and all that is irregular, all crystals that stick together, etc., should be removed, and may be remelted and used as a cleare for sugar curing. The sifting also separates bits of straw and other impurities held in suspension. In Europe it is customary to classify the sugars according to these siftings, there being special markets for each number. There remains generally about 0.5 per cent that has to be remelted, while the 1 to 2 per cent of powdered sugar is readily utilized.

The sieves generally are slanting, wide, wooden troughs, which receive a rapid and lengthwise vibrating motion. The bottom of these troughs consists of three or four sieves of different meshes. The sugar moves forward on the sieve, as it does on the KREISZ carrier described under another caption, and the finest portions, such as powders and small broken crystals, are the first separated. The next sieves allow sugar of a specified size to pass through, and the last one retains what remains. An excellent practice consists in covering these troughs, so as to prevent the escape of the sugar

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[1] Z., 52, 173, 1902. [2] Z., 50, 860, 1900.

dust. Under each sieve there is a hopper attached to the trough, and terminated by a linen pipe that carries the sugar to the bags.

Of late, many sugar factories have introduced rotating devices almost exactly the same as those used in flour mills (Fig. 178 bis). They consist of a suspended compartment, *A*, having a circular motion around a central axis, *C*. The sugar crystals are introduced at the centre of the circle described upon a first sieve, and gradually

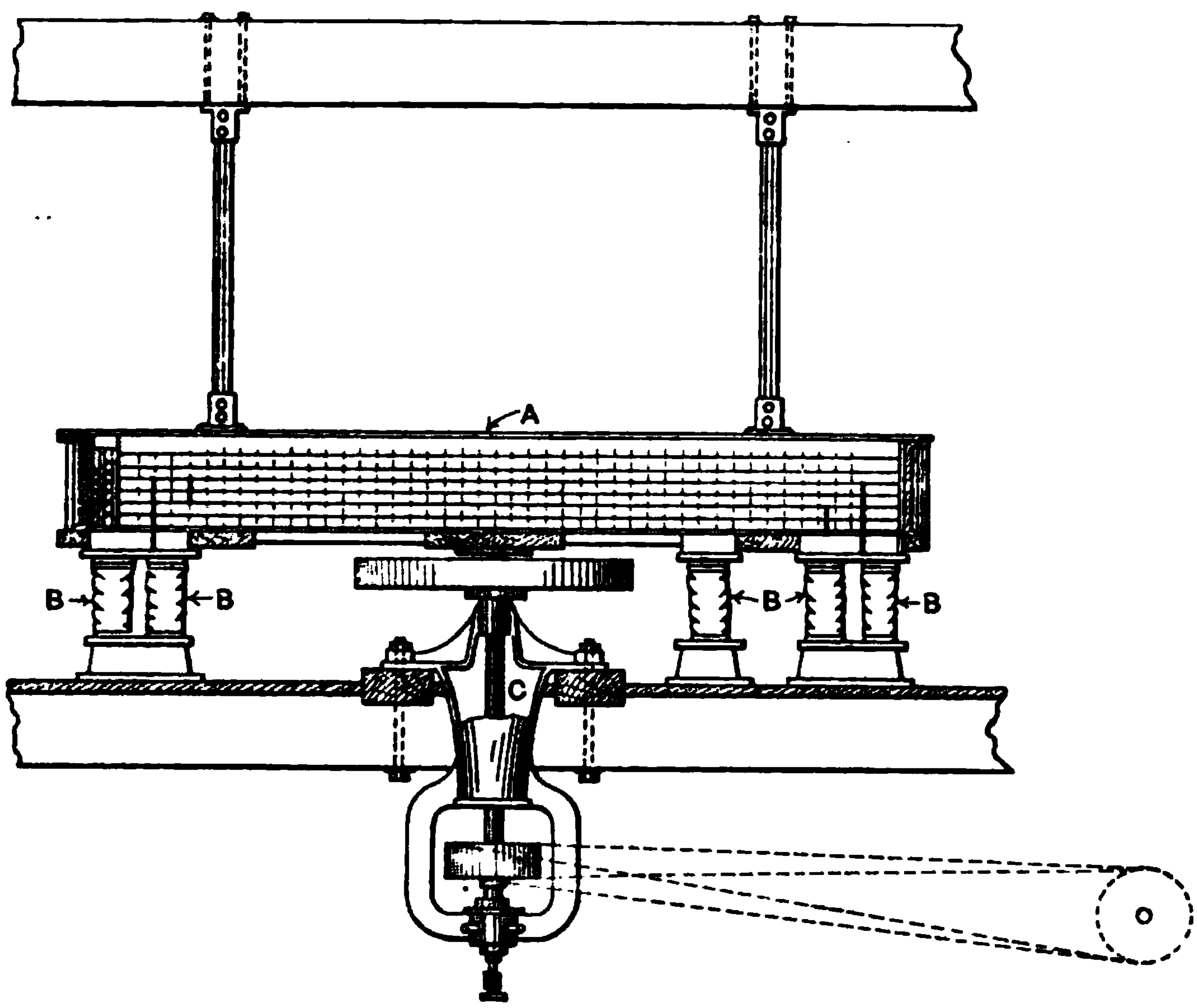

FIG. 178.—German Sugar-sieve.

work towards the outer periphery, where the refuse escapes. The finer portions fall from the first to the second sieve, and here undergo a second classification. The different products pass from the appliance through linen pipes, *B*, into the bags. Another classifier is based upon the weight of the sugar crystals. The sugar is placed in thin layers upon a large horizontal belt and rapidly carried forward with the belt. When reaching the pulley the sugar is projected forward, the distance travelled by each crystal depending upon its weight, and falls by gravity into a series of receptacles. No mention of a practical application of this method was found.

Sugar mixing.—In many beet-sugar factories it is not customary to sift sugar intended for the refinery, the idea being to mix the products so that the general appearance of the sugar shall

be uniform. The BOUTELLIER[1] mixer is among the appliances of this kind that have met with some favor. It consists of a cylinder with a conical bottom, divided into twenty compartments by radial partitions, these compartments having a total capacity corresponding to five bags of sugar. The compartments are open on top, and are closed at the bottom by small trap doors, which may be opened independently for each section. Above these divisions, on the axis of the main distributing cylinder, is a distributing cone with a point turning upward. The cone receives a rotary motion from a special system of transmission. Below the trap doors of the compartments is the mixing cylinder, revolving around a horizontal axis, this cylinder being partly divided into two sections by a partition. Below it is the hopper connecting with the bag to be filled with the homogeneous sugar. The sugars to be mixed are emptied into a common receptacle and carried upward by an endless belt with pockets, such as are used in grain elevators, then passing vertically by gravity through a pipe of medium diameter upon the rotating cone.

The sugar granules are projected according to their specific weight, and fall into the compartments previously mentioned, which constitutes the first mixing. The sugars are thus in layers in the receiving sections, and are subsequently thoroughly and finally mixed in the revolving horizontal cylinder. To obtain this result, one of the traps of the compartment is opened, the rotating drum revolves very slowly, the sugar granules simply falling one on the other. After three or four turns the motion is reversed, and the mixing is then finished. The sugar falls by gravity into the distributing hopper connecting with the suspended bags. It is interesting to note that this mixer acts also as a cooler for warm sugars fresh from centrifugals. One man can run several mixers of this type.

During a recent trip to France, the writer had occasion to examine the DENIS method (Fig. 180) of transportation and automatic mixing of high-grade sugars. This method is certainly very economical in its working, and deserves more than a passing description. The general arrangement and detail are shown in Fig. 179. The arrangement of the centrifugals is illustrated in the right-hand corner. The sugar separated and found on the drum of the centrifugal is scraped off with a small shovel and thrown into a funnel placed

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[1] S. B., Dec. 1902.

beside each centrifugal. The inside of this funnel and its connecting pipe is blue enamel, which permits one to ascertain with a certain degree of accuracy the whiteness of the sugar being handled. The

Fig. 180.—Denis-Lefevre Sugar-mixer.

smooth surface of the enamel allows a rapid passage into the endless screw beneath, the entire surface of which is also enamelled. The screw continuously feeds a vertical apron having suitable

pockets that carry the sugar to the top of the building, where it is emptied into another endless screw carrier acting as a distributor into the hoppers beneath. These receptacles contain crystals of various sizes, and may be filled as the occasion demands. Their capacity is sufficient for the contents of the entire strike of the pan, for no amount of experience can ever regulate successive granulations so that the size of the sugar crystals formed is identical. From hour to hour the composition of the syrups being treated varies, and it necessarily follows that the phenomenon of crystallization will also undergo important changes.

At the lower part of the hoppers the closing consists simply of a sliding valve, and the product falls by gravity upon a third endless screw extending under all the hoppers, which were eight in number in this factory. The screw in question can be fed from all the receptacles, or from only one at a time. It becomes evident that by this arrangement the crystals of the different strikes are thoroughly mixed during their passage along the distributing endless screw, the detailed working of which is shown in the upper right-hand portion of the illustration. It is frequently found desirable to run the sugar from hoppers through conical rollers, the distance between which may be regulated. The lumps are thus broken and the ultimate product is more uniform. Before the sugar enters the bags, it is automatically weighed in a special device suspended from the ceiling. As already mentioned, it is most important that only perfectly cooled crystallized sugar be sacked, otherwise it will soon turn yellow.

CHAPTER II.

LOAF-SUGAR MANUFACTURE.

General considerations.—The crystallized sugar, or what is known as granulated, has never been very popular among European consumers, and there is a demand for a sugar forming a porous crystallized mass and known as raffinades, and the large crystals, called sugar-candy, are still asked for in some countries. The main usage for the latter is for champagne manufacture. For direct consumption, it no longer meets with the favor it once did. The refined sugar is placed upon the market as loaves, broken sugars, etc. For exportation there are special grades and loaves that meet the demands of Eastern countries.

The general aspect of the refined sugar as consumed in Europe is that of very small crystals not readily distinguished from one another. It has the general appearance of white marble, is sufficiently hard to resist the numerous shocks to which it is submitted during transportation, and when struck gives a metallic sound. The refined sugar made in one part of Europe is very different from that made in another, depending upon the demands of the consumer. For example, the Russians give preference to a very hard product, as in some parts of the country they hold a piece between the teeth and simply suck the beverage through it. These lumps may be used repeatedly. On the other hand, in France the sugar must melt rapidly in the coffee and be made soft and porous.

The sweetening power of sugar has led to much controversy between cane- and beet-sugar experts. The methods of refining seem to be always neglected. Let the refining processes be identical, and sugars of the two origins will then have the same sweetening powers. The greater or less porosity of the final sugar depends upon the degree of tightening of the massecuite. The refining of beet-sugar consists in remelting combined with filtration, graining, and the handling of the massecuite in subsequent operations.

As a general thing, this work is done in special buildings known as refineries, although certain factories conduct both the operation of extracting the sugar from the beet and its subsequent refining. and experience shows that the two processes may be conducted satisfactorily under the same management.

It may be noted that the refiner's plant must attain considerable proportions in order to meet the daily output of an average beet-sugar factory. Usually, when the plans are judiciously made, the operations of refining not only continue after the sugar campaign has ended, but last nearly the entire year, frequently within a few weeks of the beet slicing of the following campaign. Under these conditions the invested capital does not remain idle nine or ten months of the year. The sugar that cannot be directly used for refining is converted into granulated.

The refineries that are compelled to accept the raw sugar from the factories submit the product to an operation known as "affinage," by means of which a crystallized sugar is obtained. This process is conducted in the centrifugal, curing the sugar by one of the methods mentioned in the foregoing. The raw sugar is mixed with a syrup of greater or less purity, so that it has the consistence of a massecuite, and is then run into the drum of a centrifugal, the curing being effected as usual. In some refineries efforts have been made to introduce the continuous centrifugal for this purpose, but the results were not satisfactory. To produce the highest types of refined sugar, it is well to start with the purest possible product. PELLET urges that no sugar should be melted unless it has a polarization of at least 98.

Remelts.—Sugar is dissolved in very pure water containing very little lime. The solution may be made in any receptacle with agitators. Water and sugar are simultaneously introduced, forming a syrup of a density of from 32° to 40° Bé., depending upon the factory. Evidently it is not desirable to use water in excess, as this must be subsequently evaporated. It is important to keep the saccharine solutions alkaline, so as to prevent the destruction of sugar by micro-organisms, but a much lower alkalinity is necessary than in the beet-sugar factories. During the solution of sugar it is found desirable to add a small quantity of lime in the form of powder, so that the ultimate alkalinity of the syrup obtained will be about 0.005 per cent of lime. Some sugar experts [1] claim that

[1] D. Z. I., 23, 1147, 1898.

this lime addition is a mistake, for it decreases the yields; and in this connection it has been urged that sugar refineries should never be built in close proximity to a large industrial centre or near a railway station, as, in such cases, the air is saturated with carbonic acid, and the requirements for lime become greater with a corresponding sugar loss.

Filtration.—Formerly great importance was attached to the clarification and epurating syrups, but later scientific observations have shown that these operations are not as essential as was once supposed. Numerous processes came into use, but most of them are now obsolete. To the syrup was added from 2 to 4 per cent of pulverized boneblack and 1.5 per cent to 2 per cent of coagulated blood, and the mixture boiled. The albumen of eggs, intended to carry down the impurities, was for a long time in use. In a good many refineries boneblack continues to be employed. Experts, such as AULARD,[1] consider this substance necessary for the filtration of the syrup of remelts, and claim that it removes 14.8 per cent of the total impurities.

The presence of calcic salts in the refined products is due to the water used, the raw sugar, and the lime added to obtain the desired alkalinity. The boneblack filtration will carry off a portion of these salts and decrease the alkalinity, which diminution continues even after the boneblack has ceased to act. The analysis of the cleares will give an excellent indication as to whether the boneblack should be renewed. JESSER[2] recommends that these salts be changed into chlorids by the use of chlorid of barium, under which conditions the boneblack is more active in its effects.

The filtration in refineries continues to be carried on in vertical cylinders 10 meters high and filled with boneblack, the grain varying somewhat in size with the work to be done. The syrup is run through a battery of these filters until the decoloration is completed. When the efficiency of the product ceases, it is washed in the filters and is then allowed to ferment. This is followed by the action of a diluted hydrochloric acid solution, and after a final washing it is dried and heated to red heat in special boneblack kilns, in which a revivification is effected. All these operations are expensive and very dirty, and the boneblack itself soon becomes a centre of infection.

Before the affinage was used in refineries, the consumption of

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[1] IV Congrès, 2, 106, 1902. [2] D. Z. I., 23, 1290, 1898.

boneblack reached enormous proportions, frequently representing twice the weight of raw sugar melted. By more modern modes of working, this amount has decreased considerably, but still is an item of great expense, and every effort continues to be made to do away with it altogether. As early as 1865 Basset[1] pointed out that the refining of sugar would sometime be accomplished without boneblack, and that it was useless to attempt any improvement in the then existing types of mechanical filters. These conditions realized in the Soxhlet[2] process. Sugar is dissolved in cold water, to which is added wood flour and infusorial earth, and the mixture is run through filter presses, or subjected to any method of mechanical filtration. According to Lippmann,[3] 0.1 per cent of this preparation is sufficient to obtain thoroughly filtered juices. The sugars made by this process are said to be ideal, and compare favorably with those obtained by the boneblack methods.

Brendel and other experts claim that one of the essential advantages of the Soxhlet method is, that the syrups may be kept at a comparatively low temperature up to the moment that they enter the pan, and this, in consideration of possible sugar losses, is an important gain. In some of the most recent methods of refining, the syrups are circulated through tubular reheaters until they reach a temperature of 90° to 95° C. before being run into the vacuum pan.

Graining.—In general, the graining in pan for sugar refineries is done according to the same methods and in the same apparatus as in the beet-sugar factory. The European refineries are not prone to use the enormous vacuum pans that have found a certain vogue in America. Their argument against them is, that through their use the dangers of sugar decomposition are increased, owing to the enormous pressure of the massecuite upon the heating surfaces, resulting in higher temperatures. On the other hand, in the United States the pans are conducted at a higher vacuum than in Europe, and this in itself does away in a measure with the supposed objections. It is customary, in factories visited by the writer, to grain at a comparatively high temperature. Among the advantages it is claimed that the resulting grain has considerable power of resistance.

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[1] Z., 15, 502 and 573, 1865.
[2] Z., 43, 969, 1893.
[3] Z., 43, 683, 1893, and 44, 630, 1894.

As the final sugar obtained in a refinery is not the same as that of a beet-sugar factory, there are necessarily certain points of difference in the manner of conducting the strike. The nucleus of the graining is of considerable volume, and there results a great number of crystals. As the crystallization advances quickly, the grain is rapidly fed by the introduction of syrups, and the entire operation is completed after a comparatively limited interval. The water allowed to remain varies according to the hardness of the final sugar to be produced. The water percentage may be said to be about 12.

Massecuite reheaters.—The massecuite is received in a reheater, in which the temperature is kept uniform during the entire period when it is being run into the moulds. An apparatus of this kind is the HASTIE reheater, shown in Fig. 181. It consists of a cauldron

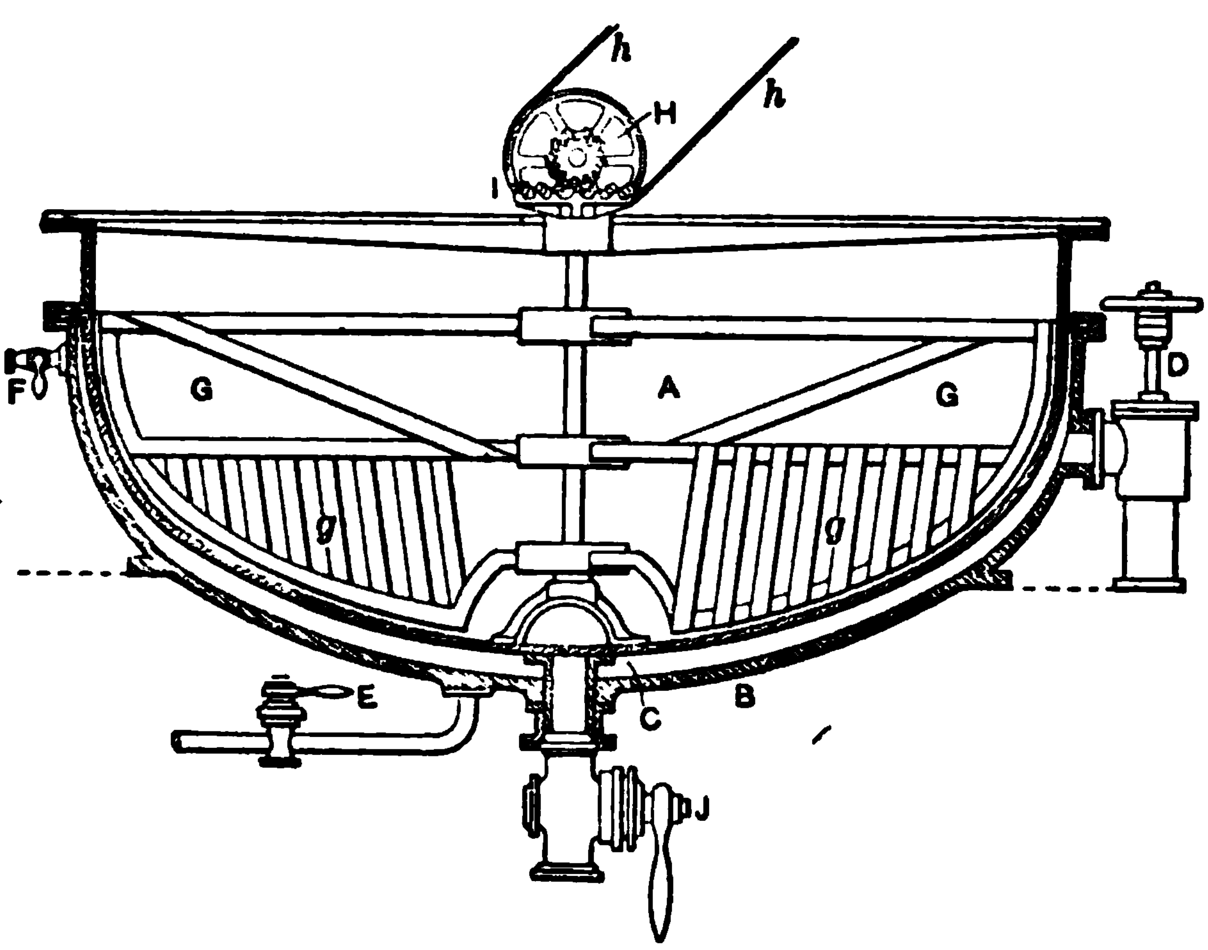

FIG. 181.—HASTIE Massecuite Reheater.

with double bottom, *B*. There is an agitator, *G*, which receives its motion from the conical gearing, *HI*. Steam is introduced into the double bottom through the valve, *D*, and the condensed water runs off through *E*. The massecuite is run into the moulds through a bottom pipe, which is regulated by *J*. The product is then at about 80° to 85° C. It is important that this temperature be not exceeded, otherwise the product will stick to the sides of the moulds, as the mother liquor then tends to crystallize in the cracks of the enamel. However, the massecuite should be sufficiently heated and the moulds filled with considerable care, so as to prevent the

distribution of air bubbles through the mass; furthermore, the mould should be warm and absolutely dry. Precautions must be taken to prevent any crusts or lumps, formed in the reheater, from finding their way into the moulds, as they would have to be remelted or ground to a flour.

Moulds.—At first, in the manufacture of white-beet sugar, the cane-sugar methods were followed. The moulds were of terra cotta, then of papier-maché, and for a time sheet-iron moulds were also used. Then KINDLER[1] proposed that they be tin- or zinc-

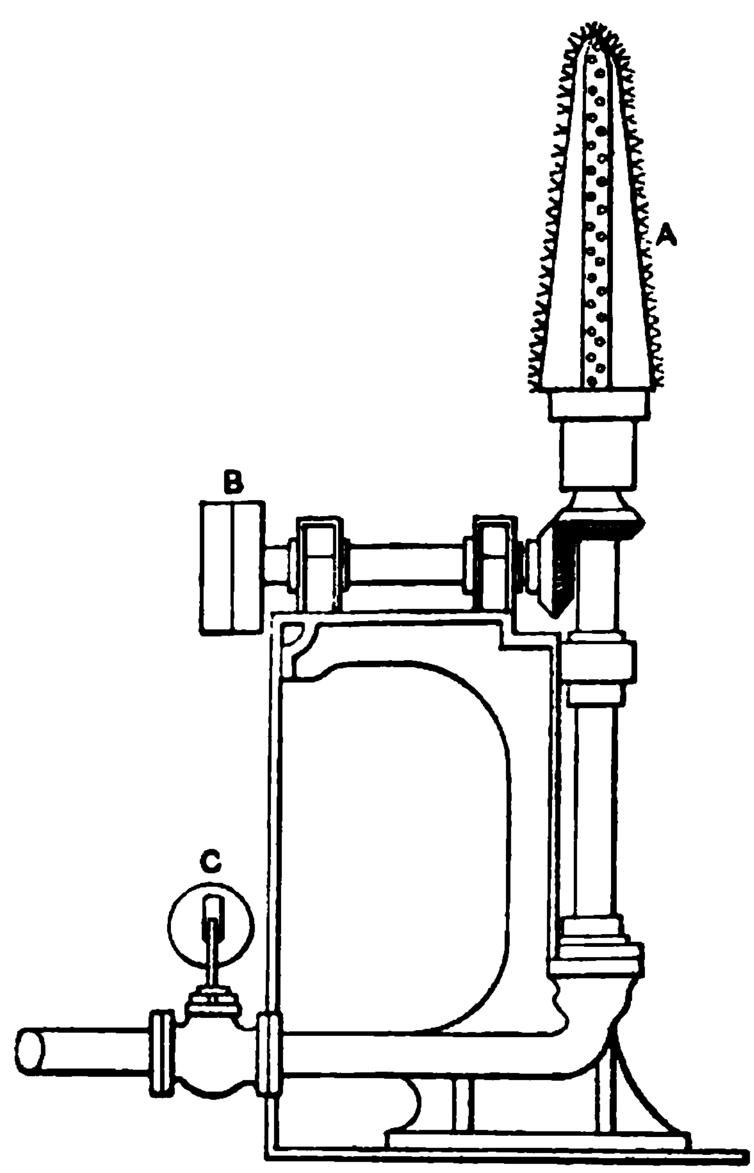

FIG. 182.—Mould Washer.

lined, and finally the sheet-iron moulds enamelled inside came into use. Whatever the shape of the mould, every precaution should be taken to prevent rust spots, as they will color the sugar; and the moulds should be kept excessively clean by thorough washing after each emptying, otherwise there will be danger of fermentation, which affects the color of the loaf, giving it a blackish hue.

The washing of the moulds may be accomplished in various ways. The method that especially attracted the writer's attention, and which has had a certain vogue, is shown in Fig. 182. It consists of a perforated conical brush, *A*, which is made to revolve by the

[1] Z., 49, 363, 1899.

conical gearing under the command of the loose and fixed pulleys, *B*. The mould is placed over the brushes, which are then set in motion. The water circulation is under the control of the pedal, *C*, and, as it penetrates the perforations of *A*, performs the work most thoroughly in a few seconds. As a certain amount of sugar is dissolved, the sweet water is collected in a receptacle beneath. This water is taken back in the work; but, as it offers an exceptional opportunity for the development of all kinds of micro-organisms, it should always be kept at a high temperature, say 75° to 80° C., in order to avoid sugar losses.

The OPPEMANN [1] device for washing requires the use of steam, which circulates inside and outside of the moulds, and, condensing along their surface, effects a thorough cleaning. The lower parts of the moulds are closed by suitable stoppers or corks. The mother liquor runs off through these openings when the loaf has sufficiently settled.

Filling.—The moulds are all arranged upon special tables with their points downward. The better plan is to have them upon small cars, which may be placed under the reheater; while another arrangement consists of a movable distributor moving successively over each mould, or each row of moulds, on the respective tables. In some cases the cars have six openings, so that the moulds may be filled in series of six, coming successively into position, by which means considerable labor is saved. Another very simple method for filling consists in using a long rubber pipe with a suitable valve at its extremity.

Whatever system is adopted, the filling and mould room should be kept at a temperature of not less than 30° to 35° C., and every precaution should be taken to prevent draughts.

Stirring.—Some minutes after the filling a crust will form upon the surface, which must be removed by gently stirring the contents of the moulds; for if the upper crust were allowed to remain, the cleare used for curing could not penetrate the mass. This upper crust must frequently be removed not less than three times. The stirring is done with a double-edged wooden blade, and demands not only care, but also considerable experience, because the pleasing aspect of the resulting refined sugar depends upon the manner of performing this operation. The portions of the sugar which the blade does not reach will have a yellow hue; and, if the stirring

[1] Z., 50, 356, 1900.

is done when the mass is too hot, all the crystals will have a tendency to fall to the bottom point, while, if done when the mass is too cool, the crystallization will not be uniform throughout the loaf. For the completion of the solidification, at least from 8 to 12 hours are needed, during which interval the stirring should be done three times. The mass then is white.

During this cooling, there is first an increase in the size of the crystals, which are fed by the very pure mother liquor surrounding them; then follows another crystallization which cements all the small crystals together. The porosity of the loaf depends upon the manner in which this last phase takes place. The more complete this cementing, the fewer will be the interstices for the circulation of the cleare. If, on the other hand, this transformation is incomplete, there will be no adhesion between the crystals, and the slightest shock will be sufficient to break them apart.

Purging and curing.—When the necessary time has elapsed, and the loaves are sufficiently compact, the bottom plug is removed; and the moulds are allowed to drip at a temperature of from 25° to 28° C., for 5 or 6 days, depending upon the conditions of viscosity, etc. The drippings are collected in a special reservoir. The curing then commences, and lasts two days, at least three or four cleares being necessary. No final steam purging is possible. It is essential that the last cleare shall be limpid and white. Some refineries follow up the last sugar cleare by a short water curing, and experience shows that this has the advantage of leaving the sugar less hygroscopic than the regular cleares.

There are advantages in giving the cleares a slight alkalinity, and they are distributed in quantities determined upon in advance. Before the new cleare is added, sufficient time must elapse for the preceding one to have passed through. For tight-grained sugar, the cleares used are rather fluid, so that they may circulate rapidly, while, on the contrary, for porous and soft sugar a thicker cleare is preferred. The concentration varies from 70° to 76° Brix. If the cleares are too thick the general working is slow; if too thin they dissolve the sugar and destroy its crystalline aspect. When the loaves are not sufficiently tightened, a cavity will frequently form in their interior. On the other hand, if they are too hard there will be portions where the curing is ineffective, and the sugar at those centres will have a yellow hue in spite of all efforts.

Cups of every kind are used to distribute the cleare upon the moulds. The Rossak cleare distributor has a hollow handle, to

which is attached a flexible pipe. The cleare passes through it, then into the hollow handle of the spoon, in which is a small valve that may be worked by means of a lever placed along the side of the hollow handle, a spring closing the valve as soon as the lever comes to rest.[1]

The loaves should be blued, as is done with any white sugar; in fact, it is even more essential in this case, for there is always a tendency for loaf sugar to appear yellow, whatever care may have been taken in its production. STEIN[2] attributes this phenomenon

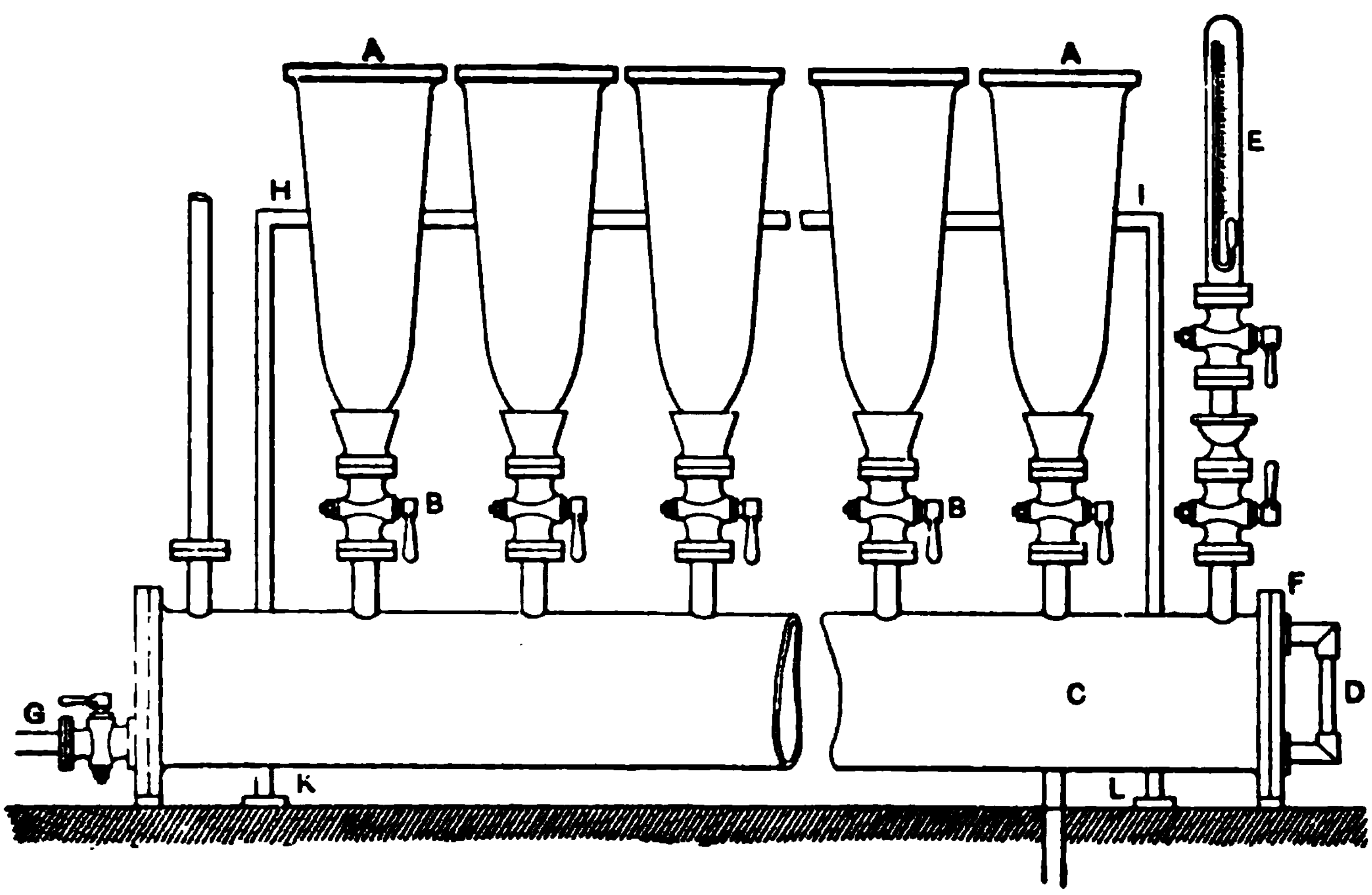

FIG. 183.—HIKL Purging Apparatus.

to the impurities of the cleares used, or to a precipitation of iron carbonate present in the water. The most practical way of using the marine blue in this case is to add a small quantity to the pan during the last period of the strike.

It is evident that the purging demands considerable time and labor. All these operations may be much simplified by the use of a series of suckers. Under a table, HIKL (Fig. 183) places rubber joints well fitted upon the points of the moulds. These joints connect with vertical pipes on which are suitable valves, *B*, and at the other end of which is a horizontal pipe, *C*. Connection with the vacuum is made through *G*, and *E* is the vacuum gauge. Under even a comparatively slight vacuum the purging is most complete, and, instead of taking seven or eight days, the operation is entirely and most satisfactorily terminated in two.

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[1] Oe.-U. Z., **33**, 697, 190, 1904. [2] Z., **10**, 349, 1860.

With the idea of obtaining a thorough distribution of the massecuite in the moulds, PASSBURG[1] draws the cleare through the mass not downward, but upward, so that all the air may escape. The moulds, which are conical in shape, communicate at their apex with a horizontal pipe, having a series of branches, connecting with the air pump. This pipe revolves around its axis, so that the loaves may be turned and placed in any desired position, with the apex pointing upward or downward, as the case may be. The washing

FIG. 184.—SCHEIBLER'S Apparatus for Curing Under Pressure.

is done with the apex pointing upward until all the cleare has been absorbed by the loaf, after which the position is reversed, so that the washing may be more rapidly effected. After the cleare has escaped, hot air is forced through in the same direction, and the loaves are thus rapidly dried.

The SCHEIBLER[2] mode consists in placing the forms with point upwards (Fig. 184). The moulds, with their contents, are placed upon a rubber ring, *b*, which forms a tight-fitting joint. The point enters into a conical ring, tightly held by means of the screw, *f*, *e*. The covering terminates in the shape of a pipe, *d*, which connects it

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[1] D. Z. I., 28, 866, 1903. [2] D. R. P., 115,291, 1899.

with a basin, *d*, receiving the after-product of the mats. The curing liquor is introduced from the bottom at *g*, and escapes at the top. The amount entering the receptacle, *d*, is shown by the side graduation, d_2, and is always the same for the product of the same strike. When the desired volume of cleare has passed through, the pressure of the screw, *f*, *e*, is released, and the conical top is taken off. The receptacle, *d*, is tilted over around a pivot and the after-product is run into a gutter, *k*, used for all the moulds of a series. Numerous other modes of purging have been invented, many of which are worked upon the principle of centrifugal motion. These will be examined under another heading. By all the old methods the dripping, as before said, lasts for four or five days.

After the cleansing the base of the loaf is scraped level with an instrument having a special shape, or with a milling machine, after which the loaves are taken from the moulds and again placed in position for a certain time, the point being first left upward, and, after a day or more, pointed downward. Under these conditions the small portions of syrup that may remain in the mass become more equally distributed. The loaf then has its final shape, and is left exposed to the air for 24 hours before being sent to the dryer. The bottom is cut off, and the top is turned on a lathe. In some factories this operation is performed only after the oven drying.

Loaf centrifugal.—It has been mentioned that the centrifugal has taken the place of the now obsolete SCHUEZENBACH method for the manufacture of raw and granulated sugar. In the same way, there is a tendency to give preference to centrifugals rather than to old methods of curing, which demand much time and labor.

The first experiments in centrifugal curing were those of VAN GOETHEM,[1] in 1850, but the first practical application was developed by FESCA. The main difficulty was, that the loaves would break during the centrifugaling. The FESCA[2] method required the use of a pump, forcing oil at 100 atmospheres into the bearing of the apparatus, which was combined so that two velocities were obtained, and this is an indispensable condition for success, as will be subsequently explained. A centrifugal of this type is made by BREITFELD and DANEK (Fig. 185). The moulds are placed in the drum, *D*, and are arranged in two rows, *A* and *B*, with ends pointing

[1] Z., **1**, 438 and 452, 1851.

[2] Z., **32**, 218, 1882.

outward. The pulley, *C*, receives its motion from a belt running on a pulley keyed on a horizontal shaft. There are two of these, moving at different velocities, under which conditions the drum of the centrifugal may be made to move at two different speeds. The apparatus of this kind have, in most cases, an exterior diameter of at least two meters. Great care is needed in starting them, and electrical motors have been found satisfactory for this purpose.

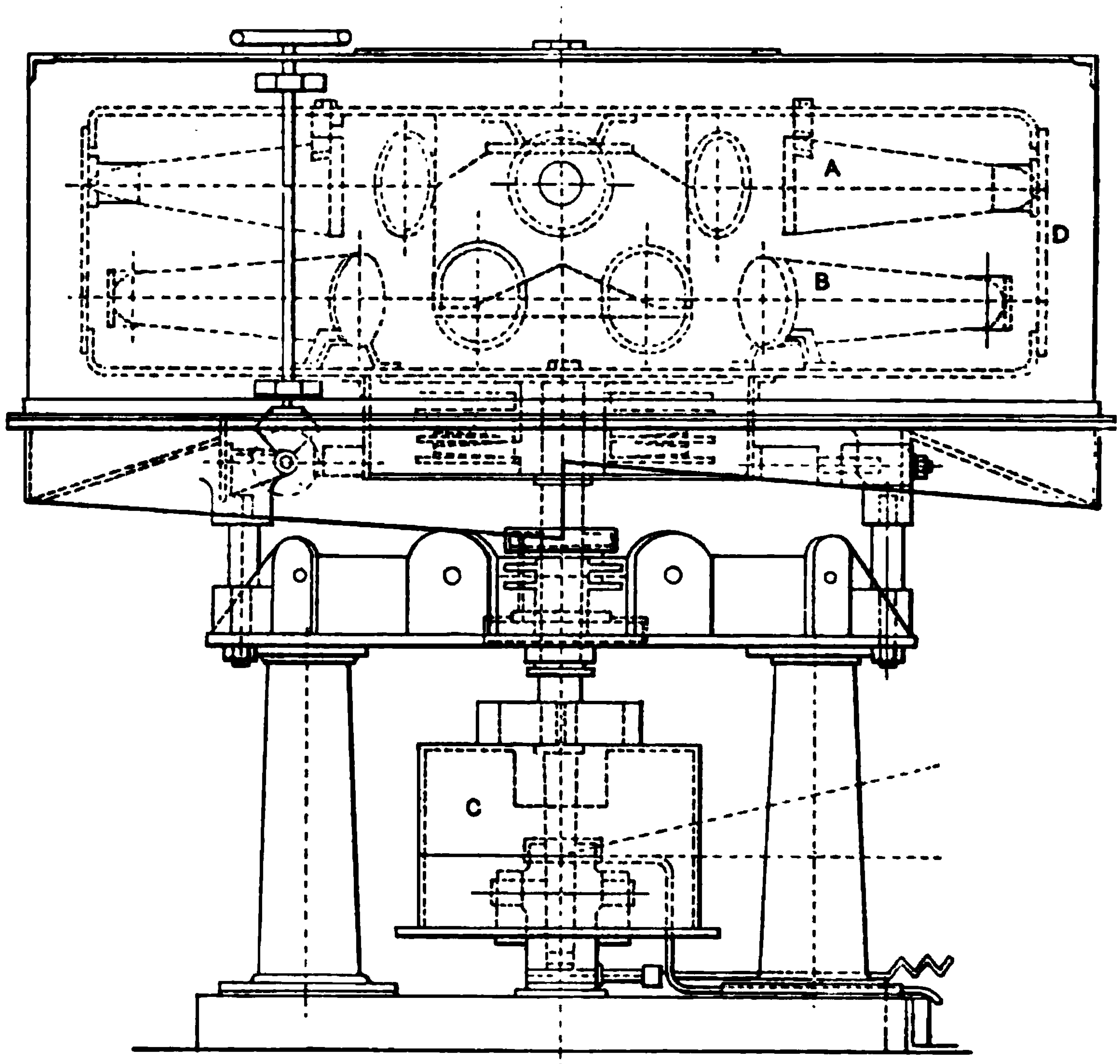

FIG. 185.—BREITFELD and DANEK Loaf Centrifugal.

It is to be noted that the massecuite for loaves worked under these conditions must be grained much tighter than when other methods are used, as they will the better resist the force to which they are subjected. The curing and purging being done rapidly, the fault found with tight graining no longer holds in this case.

In the WOLF [1] method of working sugar loaves in centrifugals, the loaf to be freed of its syrup is placed in the drum of the cen-

[1] S. B., June, 1900.

trifugal before it has entirely cooled, at 44° to 66° C. The syrup adhering to the crystals is thus more readily swung out. In a very few minutes the loaves become perfectly white, two cleares being sufficient to complete the operation in a most satisfactory manner. Practical experiments have shown that the best results are obtained by making a hole two inches deep in the bottom of the loaf when it is soft; under these conditions the cleares do not overflow on the sides of the loaves, a very small volume being necessary. The loaf, leaving the centrifugal while still hot, dries rapidly. On the inner periphery of the drum is placed a perforated circular steam pipe.

Another loaf-sugar centrifugal possessing some excellent characteristics is the KACZAROWSKI [1] apparatus. At the lower part of the drum is a small revolving spiral gearing with six rings, to which is given a comparatively slow motion; these gear with other rings on which the moulds with their contents are suspended. The loaves do not point to the central spindle, but rather in the direction of a tangent to the drum. The loaves make four revolutions per minute, and the centrifugal spins at a velocity of 350 revolutions during the same interval. The cleare passes through the loaves in a spiral direction and accomplishes a very thorough curing. This centrifugal has two hoppers for the reception of the cleare, one to distribute it to the upper and the other to the lower row of moulds. For a still greater regularity in the distribution of the cleare, it is received in an inverted funnel divided into six compartments by vertical divisions. Each of these sections corresponds to a mould, and by this combination the loaves all receive exactly the same volume of cleare.

The VIVIEN [2] proces sfor handling the moulds and contents in centrifugals has some special features that are worth recording. It is recommended that the strike from the massecuite consists of very closely formed crystals obtained at a comparatively low temperature, by which method there is formed a soft and very soluble sugar. The cleare used is at 30° Bé., and is followed by a steam curing for twenty seconds, then with a liter of cold water, and for half a minute before the centrifugal is brought to a standstill the steam cock is opened. This very moist sugar is submitted to a settling operation in a special mould, and the cake thus obtained is subsequently dried.

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[1] C., **11**, 856, 1903. [2] S. I., 8, 217, 1873.

The loaves worked in centrifugals are not always satisfactory. One of the main reasons is, that the opening of the point of the moulds is entirely too small for the escape of the after-product from the cleare. Excellent results have been obtained by removing about three centimeters of this point and placing a small piece of metallic cloth in it. This holds the loaf, and offers a considerable space for the escape of the swing-out syrup. Under these conditions it becomes possible to submit a moderately tightened massecuite to the centrifugating, and the final sugar obtained will have a much more pleasing aspect.

The working by the centrifugal method is always based upon about the same idea. The loaves in the forms or moulds are cooled to about 30° C., and are then placed in the centrifugal. The apparatus is first set spinning at a low speed, and when the mother liquor appears to be entirely separated the velocity is increased for a short time, and then reverts to that given at the start. The curing begins with a number of cleares, depending upon their concentration and the nature of the sugar being handled. The operation ends with high speed for a few seconds.

Drying.—The loaves obtained by the ordinary mode of curing are left in the air for 24 hours before being placed in the dryer, as the cleare they still retain, in greater or less quantity, might during the drying operation redissolve some sugar, and, furthermore, if the loaves continue moist to the touch, their subsequent drying will result in a spotted surface. When the sugar is very porous the defects are mainly centred at the bottom or in the centre of the loaf. The dryers are rooms of any shape containing series of shelves for holding the loaves, and are arranged so as to permit of suitable ventilation. The dryest and hottest air should circulate upon the dryest loaves; otherwise a condensation upon their surface results, which would lessen the market value of the product. When the drying is not properly done, there is formed a rough and almost impenetrable surface.

The system of heating the dryers is now confined entirely to hot air or steam, the hot-stove mode having become obsolete. The drying under vacuo has been attempted several times, but has never met with the hoped-for success. A description of PASSBURG's dryer, only recently introduced, is of interest. He points out that exceptionally small-grain sugar loaves crack under vacuum, but that by his method the difficulty may be overcome by allowing the heat to increase slowly. Under these circumstances the loaf

has about the same temperature throughout the mass. This is accomplished in the following manner:

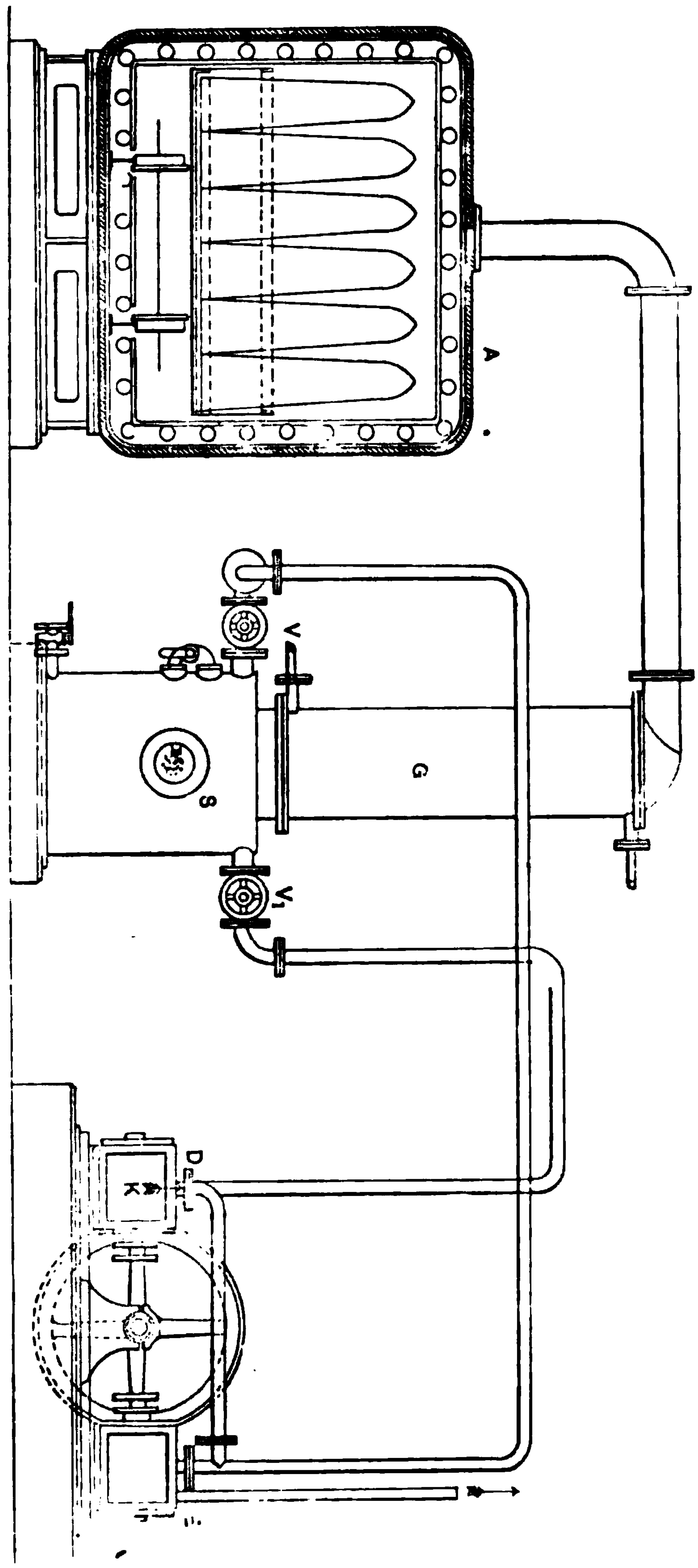

Fig. 186.—Passburg's Drying Method.

The loaves of sugar are introduced into a closed receptacle, *A* (Fig. 186), and are there heated, either by hot air receiving its caloric

from steam pipes, or by any other means of heating. It is important to keep this compartment closed, so that the air circulation may be kept under control, and thus obviate any danger of cracking the loaves. About 12 hours at 75° C. are needed for this drying. The air is then removed. The loaves are submitted first to a high vacuum and then to a very low vacuum, special valves being necessary, that the drying may be regularly continued. As the loaves must be gradually dried, the comparatively low vacuum must continue for a considerable time.

The surface condenser, *G*, has two valves, *VV′*, suited for a double-acting air pump. The valve, *V*, through a special pipe communicates with the cylinder of the air pump, *E*, intended for low vacuum. On the other hand, *V′* is intended for high vacuum obtained through the communication with the pump, *D*. By this arrangement the pump, *E*, draws off the moist air, until the maximum vacuum of that apparatus is reached, after which, and only then, does the pump, *D*, begin to work. By closing *V* and opening *V′* the change is made. It is to be noted that the PASSBURG apparatus, even when there is a large number of dryers, allows the connection of one or several of them with the air pump, *D*, for high vacuum. The drying thus continues, without changing the continued action of the vacuo, by connecting the pump with other appliances. If the arrangement of double communication, such as *V* and *V′*, did not exist, it would be necessary to have several compound air pumps instead of one.

In Fig. 187 is shown the section of a partly dried sugar loaf. *K* is the portion that remains moist, and *M* the part where the drying is completed. When submitted to a temperature of about 45° or 50° C., the temperature at *K*, even after 6 to 9 hours, is only about 35° C. Sugar being a poor heat conductor, the drying operation is necessarily very slow. When the heating is stopped, or when cooling is resorted to, the exterior portion of the loaf will, through radiation, transmit heat to the cooler portion near the centre, equalizing the temperature throughout the mass. Notwithstanding this fact, the loaf may crack when the product is submitted too suddenly to a high vacuo. It is to be noted that the action of this high vacuum only commences when the first stages of the drying are finished.

FIG. 187.
Faulty Loaf.

The average temperature of a dryer is 50° C.; beyond that point the loaves have a tendency to crack. Certain precautionary measures are necessary during the drying. The temperature should be gradually raised, and, when the operation is completed, slowly reduced, so as to avoid cracking during the cooling. The drying need last but three days, which shows a progress compared with the five or ten days formerly needed.

Sugar-loaf wrapping.—When the loaves are thoroughly dried the bottoms are planed off, the tops turned on a lathe, and they are then ready for wrapping. In Continental Europe, sugar loaves of a conical shape are always covered with paper, the color of which depends, in most cases, upon whether the product is for home consumption or exportation. To cover these loaves neatly, always entails a certain amount of labor. Special paper forms in two parts have recently been patented, the lower one having a circular centre with six projecting strips. The loaf to be wrapped is placed in position, and the strips turned up against its sides, the loaf and strips being then covered over by a conical paper hood with six raised parts, corresponding to the thickness of the strips holding the bottom in position.

As loaf sugar is not readily handled for many purposes, the Nollet [1] innovation, which consists in slicing the loaves into horizontal sections and then breaking them up in parallelopipeds, has been generally adopted in Continental Europe, and yet it was suggested in 1856. The size of these lumps depends upon the local demand. There is necessarily considerable loss in their production, as the outer edge is round, which loss increases with the decreased diameter of the round. These residues may be pulverized and sold as powdered sugar, but in most cases they are remelted and used for cleares in some phase of sugar curing. There is a considerable waste of labor in all these handlings. Blocquel and Bivourt [2] had the rather original idea of cutting up only the lower portions of the loaves and selling the upper as small loaves. The lower rounds of an average sugar loaf, when cut up, give 80 per cent of lumps, while the loaves, taken as a whole, give only 50 to 55 per cent.[3] To-day the small loaves are actually made for Oriental countries, as they are readily carried on mule back, etc.

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[1] Z., 6, 180, 1856. [2] S. I., 9, 12, 1874. [3] S. I., 9, 525, 1875.

CHAPTER III.

SUGAR IN CAKES AND BARS.

General considerations and historical data.—To do away with the losses sustained by sawing the sugar loaves, the sugar may be moulded in bars having right-angle edges. The idea of making sugar in cakes and bars dates back some years, but only lately it has been introduced in the European factories. The first practical ideas on the subject were presented by MERISOT, according to whose plan the cooked mass from the vacuum pan was run into special receptacles having the shape of truncated pyramids. The latter, when full, were taken into a cooling room, where they remained for several hours, during which period they were frequently stirred, to render the mass of syrup—ready to crystallize and cooling gradually—perfectly homogeneous. When the blocks were taken from the iron forms they were placed in special centrifugals, with the small ends up, wedges of wood keeping them in place. The upper part of the centrifugal was closed by a circular iron lid, in order to keep the wooden blocks in place during the rotation of the apparatus. There remained an annular ring at the centre of the centrifugal, into which steam was forced. The cakes of sugar were then purged of their molasses and syrup, which was thrown from the centrifugals when they were put in motion. The operation lasted for nearly forty-five minutes, which is rather too long, but the remaining sugar has the aspect of the best refined product. It is dried in an oven, then sawed into bars, and broken up into lumps of the desired size. The sawing into bars occasions a certain loss, and numerous methods have been suggested, and put into practice, by which no sawing is necessary. The first part of the work consists of the graining in pan and the reheating. The running of the massecuite into the forms offers no more difficulty than when the conical moulds previously described are used. The forms are of varied shape, depending upon the process.

Vivien method.—The shape of the VIVIEN frame, or mould, as constructed by FIVES LILLE, is shown in Fig. 188. The frame consists of two sheets of galvanized steel, the lower ends being bent under and riveted to a flat iron forming the bottom. At the upper end the sides meet, forming a spring, and thus the sides are united. When in operatien, the distance between them may be kept constant; their elasticity facilitates the emptying. The upper and middle borders of these frames have an interior

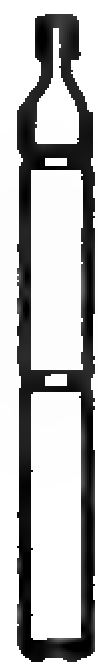

FIG. 188.—VIVIEN'S Mould.

horizontal brim, intended to support the division strips, which have a central hole or opening; their removal is very simple.

The filling of the frames takes place in a wagon constructed for the purpose. The door is shown in *A* (Fig. 189), and is marked by the handle *B*. To keep this door well in place, and assure a perfect joint, there is, on the outer edge, a groove, in which a rubber strip is placed, and a system of tightening screws keeps the door well against the joint in question. The wagon has three or four wheels, depending upon its size. The frames are shown at *G, G, G, G*, placed side by side in rows, separated by movable sheet-iron sheets with handles, *D, D*. These are tightened against each other by wooden wedges, which penetrate to the very bottom of the wagon, so that every crack is filled.

The wagon, with its frames, is placed below the vacuum pan, and the frames are filled with the massecuite. This is allowed to settle for several hours, so as to obtain a satisfactory crystalliza-

tion. The wagon is then dismantled, and the frames, one against the other, are placed in the centrifugal (Fig. 190). The latter consists of a non-perforated sheet-iron drum, *A*, having an interior diameter of 96 cm. The crown, *B*, forms with *A* an annular space, divided into six compartments, in which the frames are placed in a vertical position. A movable cover, *C*, hermetically closes the apparatus, and there are several appliances connected with the same which permit the introduction of compressed air, produce a

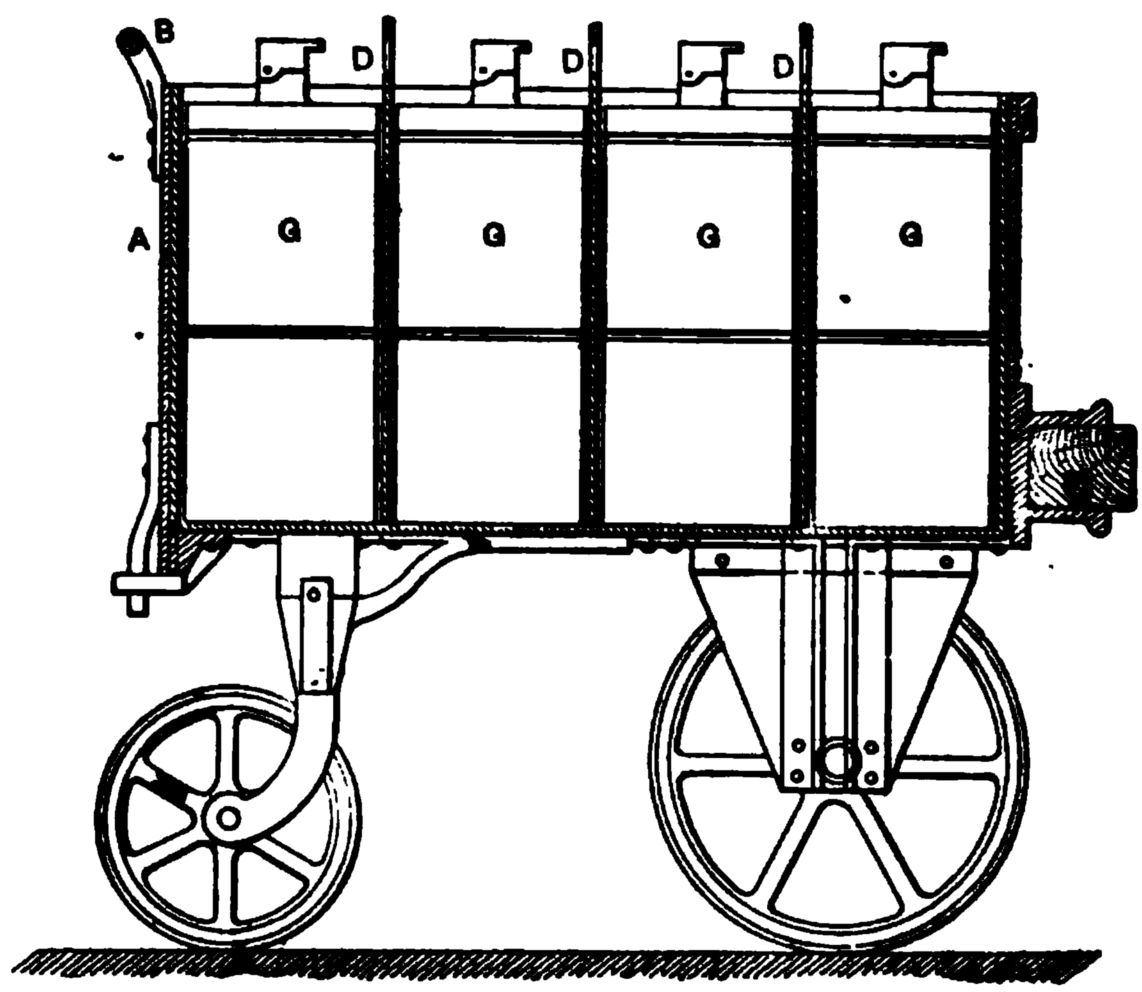

FIG. 189.—VIVIEN'S Wagon for Frames.

vacuum, or also to introduce a sugar solution into the annular space.

On giving the drum a sufficiently rapid rotatory movement by the action of centrifugal force, the syrup around the crystals is swung out through the perforated bronze plates, *D*. These are symmetrically placed on the drum, against which are the frames, side by side, kept in place by wedges and special appliances, *E*, for tightening. The syrup subsequently runs into the gutter below, from which it is taken for making second-grade sugars. The regulator is at *G*, and consists of three movable iron washers. The axis, *H*, receives its movement from below through the pulley, *I*, by a twisted horizontal belt. The lower part of the axis is a steel pivot, working in socket, *L*, in which *K* can oscillate. The working of the VIVIEN centrifugal requires a vacuum in the annular space

of the drum. After the purging action is completed, the vacuum is destroyed by opening an orifice closed with a rubber stopper. The curing then commences. The centrifugal is again closed while

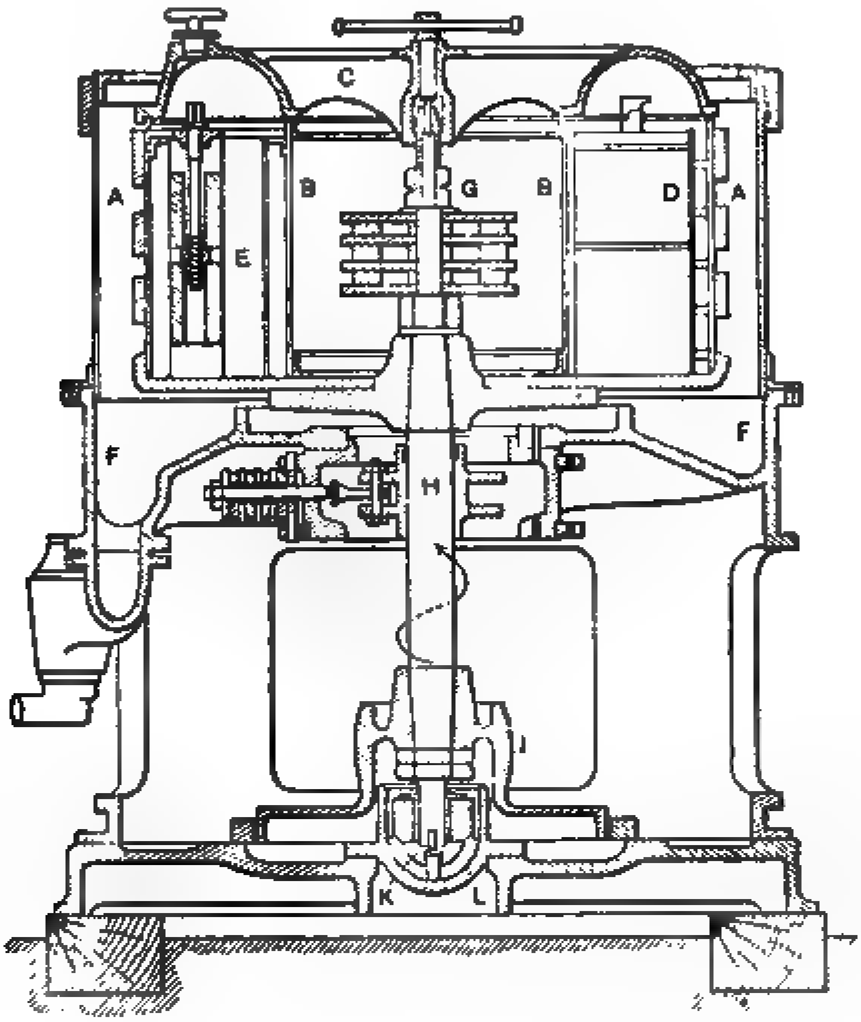

FIG. 190.—VIVIEN's Cake Centrifugal.

the cleare is being swung from the sugar; the apparatus is then brought to a standstill, and the cakes are removed after their curing is completed.

The blocks of sugar obtained are perfectly white; they are placed, however, for a short time, in a heated room to complete the drying. By this process, in less than 48 hours sugar may be placed on the market, while by the ordinary refining methods nearly fifteen days are required. The cake, *M* (Fig. 191), is seldom sold as it leaves the centrifugal; it is, as a rule, cut with a small circular saw into sections, *N*, and subsequently broken in regular lumps, *O*, and sold in boxes, in which they are arranged in regu-

FIG. 191.—Blocks of Sugar Obtained by VIVIEN Process.

lar order. The advantages claimed for this process are mainly economy and rapidity of working.

In the **Matthée and Scheibler process** the massecuite is run into a mould placed in a slanting position under the filling valve (Fig. 192). The air under these conditions may readily escape. The

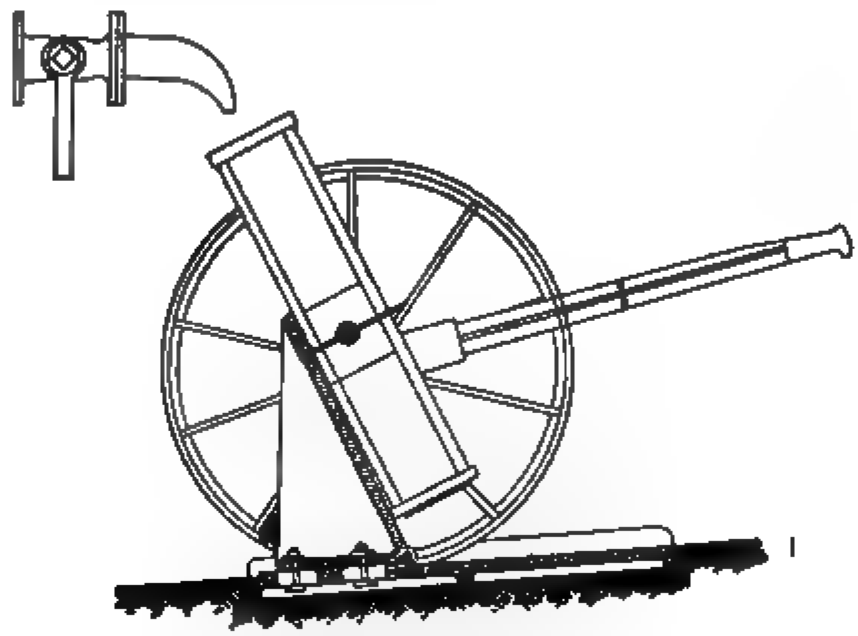

FIG. 192.—MATTHÉE and SCHEIBLER Movable Moulds.

mould is held by two journals upon wheels, in very much the same manner as the SCHUEZENBACH boxes. The interior of the box, *b* (Fig. 193), is divided by sheet-iron partitions into 12 compartments, in which, after cooling, 12 blocks of hard massecuite are formed. These blocks are separated from each other by transverse plates with openings, allowng the mas ecuite to enter and the air to escape. After a reasonable interval, the larger mould on wheels is taken apart. A screwing device works on the movable bottom, and the blocks leave in pairs. At the end of their journey they slide down a plane, which separates them from the following pair, a special device upon the middle of the table separating the clusters. The blocks are then placed in a filter press of special design, and occupy the position that the scum cake assumes after the filtration of defecated juices.

FIG. 193.—Detail and Section.

The washing or curing of these twelve blocks is the next phase of the process, and for this purpose cleares are run through the apparatus, just as water is used in the case of scum washing. The cleare circulates at a pressure of 1½ atmospheres, first driving out the mother liquor, and then washing the crystals, thus removing the last trace of impurity. At the end of the apparatus, where the after-products are escaping, a vacuum is created, and, as the syrups enter a graduated glass reservoir, one may, at the same time, judge of the quality of the cleare used and the aspec. of the after-product. The press is taken apart when the operat'on is thought to be completed. These presses are so constructed as to prevent the loss of any cleare. The blocks are then all placed in a special centrifugal, and, when the swing-out operat on has continued for the desired period, they are taken apart, the separation of the bars or cakes being readily accomplished. They are then taken to the dryer, sawed and broken into lumps, and packed.

Regarding this process, Drost and Schulz claim that, when a massecuite from a refinery is left to itself to cool, the cleare in crystallizing will cement the crystals together, and the sugar is compact in the lower part of the mass. These experts have a process of their own, in which the cakes are introduced n clusters into an apparatus consisting of a horizontal cylinder, slowly revolving on its axis. Under these conditions, any settling of the sugar at one end of the cake is impossible.

In the **Tietz-Selwig and Lange process** the massecuite, after it has been reheated, is run into long horizontal galvanized-iron moulds, which are open on top and divided into three compartments by movable partitions. These boxes are filled with massecuite until the surface is slightly above the upper border of the zinc partitions dividing the three blocks, and the mass is allowed to solidify. Before the mass is completely hard, the surface product is scraped off and made level. The blocks being hard, they are readily taken from their moulds by turning the boxes upside down upon a table and giving a slight shock. The different blocks are separated, and, in order that they may be more readily handled, they are placed in an iron frame with a handle (Fig. 194), and tightly held by means of screws and a plate, *n*. The portion, *r*, and the attachments on the other side of the frame, help to keep the frames

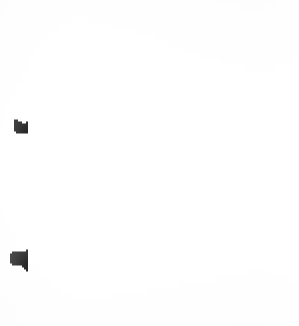

Fig. 194.—Frame for Blocks of Sugar.

in position when they are placed in the centrifugal (Fig. 195). These borders are tightly held by *S*, which are fixed by means of suitable screws. In front of each of these clusters is a perforated sheet-iron disk which holds the plates of the frames, and at the same time allows the swing-out to pass through.

After this phase of the operation is completed, the blocks are withdrawn and placed in a receptacle in which a vacuum is produced, and into which a cleare is introduced that is allowed to remain in contact with the blocks for about ten minutes. Then the blocks are placed in a second centrifugal, where the swing-out

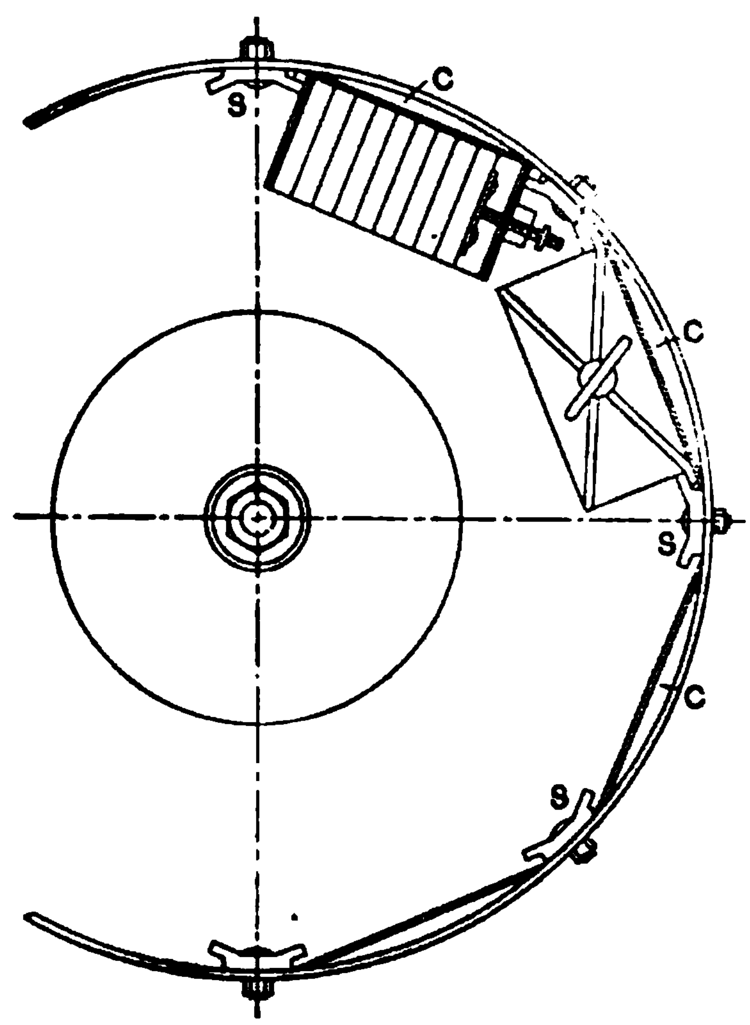

FIG. 195.—Top View of the TIETZ-SELWIG and LANGE Centrifugal.

operation lasts for fifteen minutes. The after product from this operation is used to make crystallized sugar. It is recommended that the same operation of curing be repeated in a third receptacle, then in a third centrifugal, using in this case a cleare made with a very superior sugar. After the last centrifugating, the blocks are unmounted and all the zinc divisions are removed. The cakes are arranged in suitable wooden holders, subsequently placed in the dryer for a few hours, and are then sawed up into bars and broken into lumps of a desirable size. At the factory of MERCIER & Co., Bresles (Oise), France, the results tabulated on page 447 were obtained.

A plant consisting of three TIETZ-SELWIG and LANGE centrifugals gives 20,000 kilos of lump sugar per diem.

RESULTS OBTAINED WITH TIETZ-SELWIG AND LANGE CENTRIFUGALS.

Items.	In each receptacle.	Per 100 kilos massecuite.
	Kilos.	Kilos.
Massecuite filled in moulds	75	100
Loss or waste.	5	6.66
Massecuite worked.	70	93.34
Syrup swung out.	22.5	30
Dried cakes.	46.5	62
Sugar ready for sale.	42	56
Sugar, regular sizes	33	44
Sugar, irregular pieces	9	12

Adant process.—In order to decrease the labor, ADANT proposed moulding the cakes in the drum of the centrifugal. In reality, the massecuite is run into a movable mould on wheels, which is entirely independent of the centrifugal itself (Fig. 196), and consists

FIG. 196.—Movable Mould on Wheels.

of two cylinders connected at their bottom, allowing between them an annular space, *A*, in which an annular block of massecuite is formed. This block may be removed at the proper moment and placed in a ring-like space of the centrifugal of exactly the same dimensions (Fig. 197). The annular block is made up of massecuite and a sort of metal skeleton that gives the desired shape to the blocks. The skeleton is formed by two circular bands, *J*, 75 cm. apart, and connected by eight iron wedges, *D* (Fig. 198). Four of these wedges are movable, but the four others are fastened to the lower circular band, and have on top a threaded portion which projects beyond the upper band. This permits the whole combination to be well and firmly bolted together. The entire skeleton may be lifted by means of suitable handles on top.

The space left between the eight wedges is vertically divided into eighteen compartments, and horizontally into three or four divisions by means of galvanized disks, which limit the length and

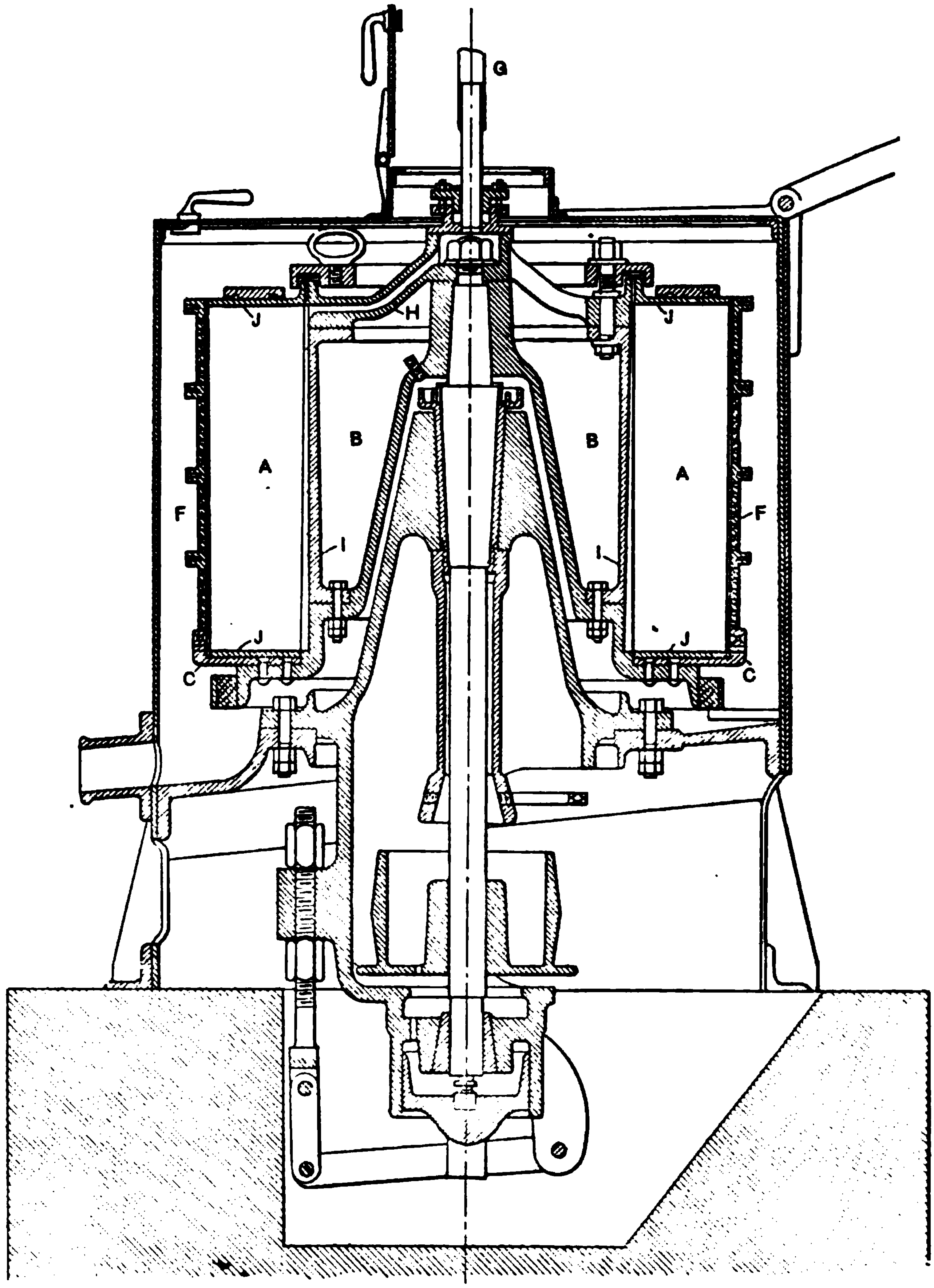

FIG. 197.—Section of ADANT Centrifugal for Sugar in Cakes.

thickness of the cakes. When filling with massecuite, another circular band with eight funnels is substituted for this upper washer. The regular band is replaced in position when the mass

is sufficiently hardened. As this takes place in the receiver on wheels (Fig. 196), the total load of the centrifugal, consisting of 475 to 500 kilos, is run in one operation. After the massecuite has hardened, which takes about 15 hours, a hydraulic crane removes the annular mould, with its contents, an places it in the centrifugal, which is then closed. This block leaves between it and the portion,

FIG. 198.—Plan of ADANT Centrifugal.

B, of the centrifugal, a space, *I*, of 7 mm. for the distribution of the cleare, which is introduced through *G* and the passage *H* (Fig. 197). The exterior portion of the block is held in position by the perforated filtering portion, *F*, of the drum of the apparatus. At the bottom it is supported by *C*, made solid to *B*.

The centrifugal is set spinning at a normal velocity of 700 revolutions per minute, and the green syrup is separated. After the speed has been reduced to 200 revolutions, the cleare is introduced into the apparatus under a pressure of about one-half an atmosphere, after which a higher speed is given to the centrifugal.

The spinning is diminished again for the introduction of a second cleare made from very pure sugar, and the velocity is raised once more to 700 to complete the swing-out entirely. With the same hydraulic crane that was previously used, the cured mass is removed from the centrifugal, and the movable wedges are taken apart. The blocks may be readily separated, and are then placed in the dryer, and subsequently broken up into lumps. The moulds must be thoroughly washed before receiving their next charge.

The filling of the moulds outside of the centrifugals has the important advantage of reducing the amount of apparatus needed. The working under these conditions is almost continuous. To each centrifugal there are 20, 30, or even 40 of these moulds, and in 24 hours one may obtain 16,000 kilos of refined sugar in each appliance. The amount of cleare consumed is 80 liters per load of the centrifugal.

The St. Quentin method.—The St. Quentin Company constructs a centrifugal very like that of ADANT, but in many respects much simpler, and having a different method of running the massecuite into the annular space. Figs. 199 and 200 represent the ar-

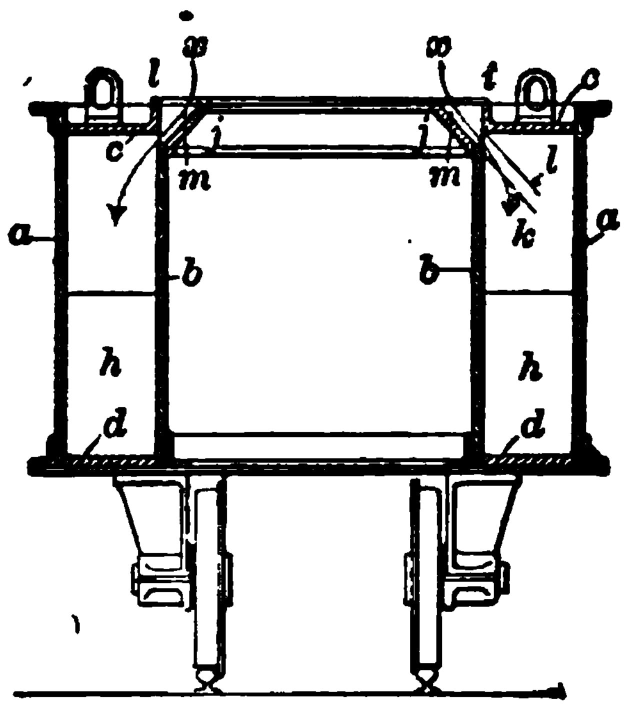

FIG. 199.—St. Quentin's Mould on Truck.

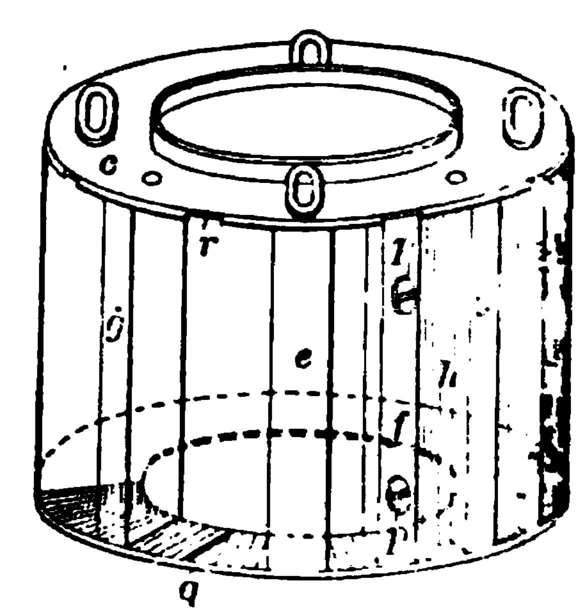

FIG. 200.—Detail of Mould Showing Partitions.

rangement and show the mould mounted on its form; *a* is the outer side, and *b* the inner side. The mould consists as usual of two circular disks, *c* and *d*, held in position by the wedges *e*, *f*, *g*; between these are placed the separating partitions *h*, *h*, etc., between which is run the massecuite, which, upon cooling, gives the bar of sugar. The upper disk, *c*, of the mould has a projecting border, *i*, and the inner surface of the form has a conical portion, *j*; the border, *i*, and the cone, *j*, form together a circular funnel, *m*,

in which flows the massecuite in the direction, x, into the compartments of the mould by the annular section, kl. The level of the massecuite is established in the funnel, m, above the circular plate, c, and under these conditions every portion of the mould is filled.

When unmounting the apparatus, the massecuite that has cooled in the funnel, m, is removed with the mould and may be readily scraped off. The mould is lifted out by the hooks, and may be suspended by the arm of a suitable crane, while the mould containing the massecuite is lowered upon a circular knife, n (Fig.

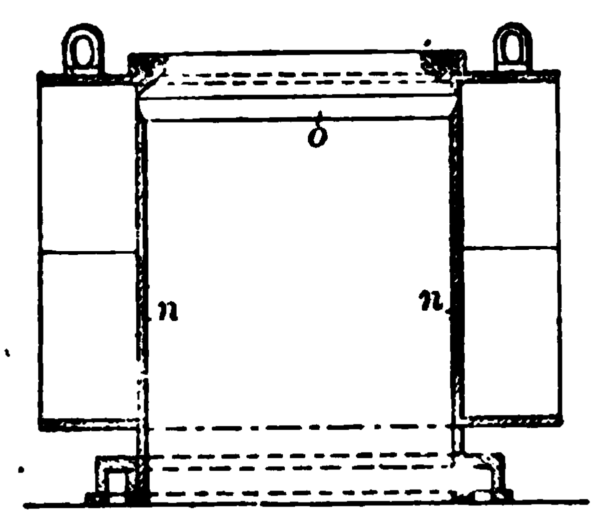

FIG. 201.—Circular Knife for Dressing the Mould Sugar.

201), attached to the ground. The cutting portion, o, of the knife may be horizontal or oblique. When unmounting the moulds of most of the combinations now used in centrifugals the upper disk, c, must be taken off. As this demands considerable labor and must be done rapidly, it is frequently neglected. By the new arrangement under consideration, c is not taken off, but, as before mentioned, c and d are braced by fixed wedges, e, g, several of which are exceptionally solid, so as to resist the pulling at the handles, c. Between these fixed wedges are other movable wedges, f, which may be put in position or taken out without difficulty, the grooves, r and q, in the disks, c and d, facilitating the placing in position of f. When taking the mould apart, the first operation is to remove the movable wedges. This permits one to handle the first sugar cakes attached to these wedges, and the divisions, h, h, etc., are then removed without difficulty. The operation for mounting the mould is just the reverse.[1]

The Huebner and Schroeder process.—This method consists in agglomerating the sugar in the centrifugal so as to form cakes. In their latest model of centrifugal, the interior of the drum is

[1] S. B., March, 1903.

divided by numerous wedges, *a* (Fig. 202). The spaces between these represent the size of the final cake. The massecuite is tightened so as to contain 6 per cent of water. This is run into a tank at 62° C., and about 6 per cent of a cold syrup at 36° Bé. is added, which mixture should be actively agitated so as to prevent the formation of lumps. The mass is then cooled to 50° or 54° C., and the centrifugal is set spinning at a velocity of 200 revolutions. The filling is accomplished in one operation. It is claimed that the spaces left by the wedges receive their share under identical conditions. The speed is increased to 1,000, and after five minutes,

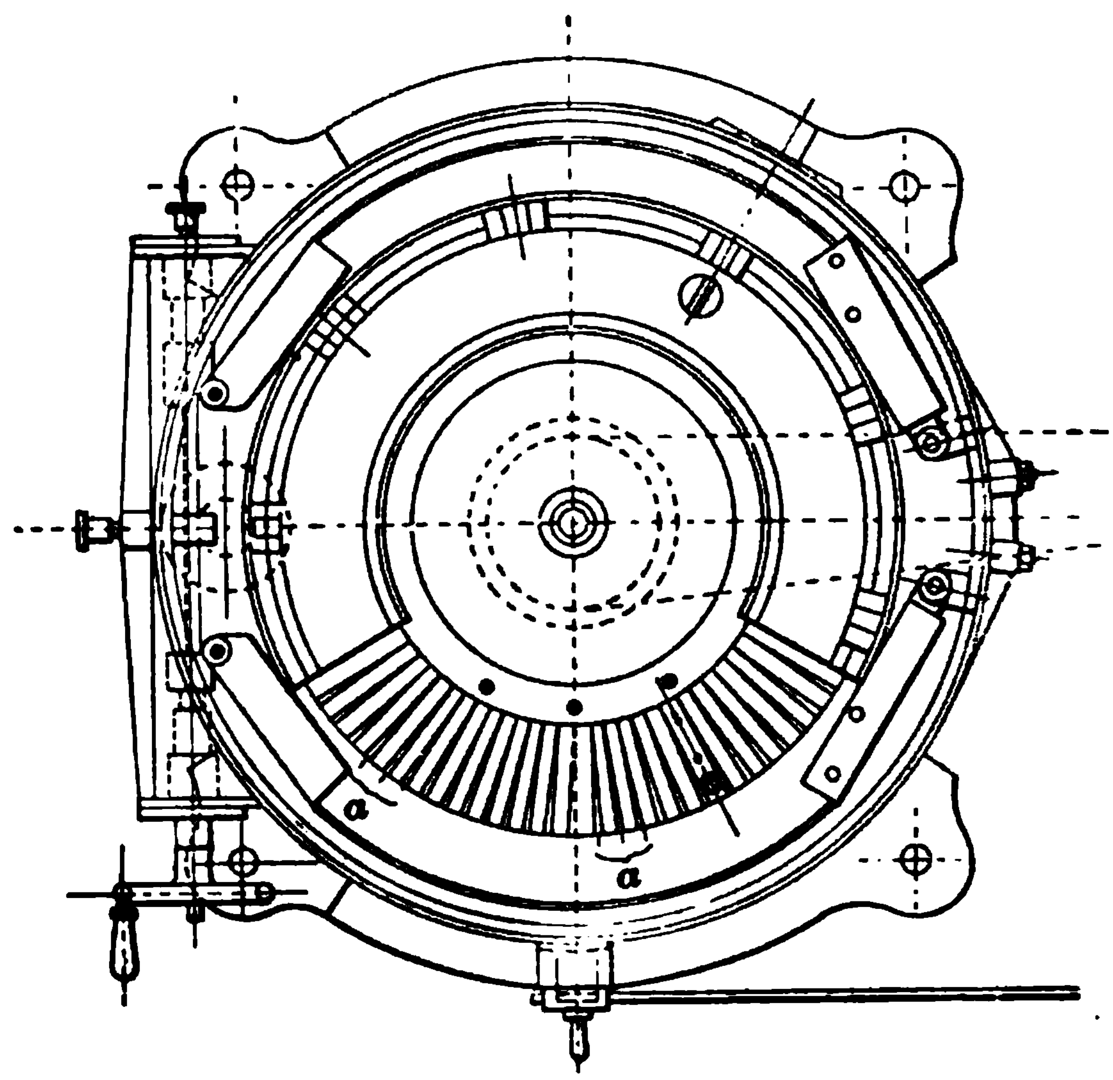

FIG. 202.—Plan of HUEBNER and SCHROEDER Centrifugal.

when all the green syrup has been swung out, it is reduced to 500, and the curing is done with about 25 to 30 liters of cleare, having a purity of 99, a density corresponding to 38 Bé., and a temperature of 94° C. A second curing is accomplished under the same conditions, but with an absolutely pure syrup, at 38° Bé. and a temperature of 94° C., made by remelting sugar wastes. This operation lasts for about three minutes. The two cleares are gradually added in small repeated doses. The spinning then continues for twenty minutes at 1000 revolutions per minute, so as to cool and dry the sugar during that phase of the operation. The hot saturated cleares crystallize in the interior of the mass, and will cement the crystals to one another. When the cen-

trifugal comes to a standstill, the sugar still retains 0.70 per cent of water. The unmounting offers no difficulty on account of the shape of the cakes obtained. These are then sent to the dryer. The sugar made by this process is sufficiently hard to be carried any distance; it may be considered pleasing to the eye, and the sides of the cake dissolve as readily as the rest. A centrifugal of this kind has an efficiency corresponding to 9000 kilos of massecuite per 22 hours.[1] In some cases the movement is given by suitable belting, in others by a triphased electrical motor.

In connection with the process just described, it is interesting to consider the manufacture of cakes intended for crushed sugar. For this there are two processes, or, at least, two methods of working. By the WEINRICH and SCHROEDER process the massecuite is run into moulds having the shape of an arc of a circle. These are cooled and subsequently placed in a special centrifugal, five of these cakes exactly filling the drum of the apparatus. The curing is conducted as usual, but is completed by a steam washing, which cements the sugar crystals together. By the FESCA process the massecuite is run into the drum of the centrifugal, treated like granulated, and cured with steam. A few instants before stopping the spinning, the steam is withdrawn and the crystals cement themselves together, thus forming one continuous annular cake, which must be broken into lumps before it can be extracted from the apparatus. As this sugar is to be crushed, the irregular shape of the lumps obtained is of no importance.

Continuous methods for the production of sugar in cakes and bars. — Numerous efforts have been made to devise some automatic apparatus for the continuous manufacture of cakes and bars, thus eliminating labor as far as possible.

The new PRANGEY combination is continuous in its action and consists of three separate parts,—a moving metallic band, upon which the massecuite becomes more or less solid; a table where it is cut into bars; and another moving table upon which the bars are broken into lumps and then dried. The moving metallic apron upon which the massecuite solidifies is fifteen meters in length; the thickness of the strip of the product depends upon the height of the distributing hopper from the apron, and its width is regulated by lateral strips. The distributor has a double surface,

[1] Fourth Congress, p. 120, 1902.

through which steam circulates, keeping the mass sufficiently liquid. In the interior are agitators which keep the product thoroughly homogeneous. During its journey upon the apron it passes over portions that are in communication with a vacuum apparatus, where the after-products are drawn off, and the purging, etc., then follows.

Experience shows that a slight heating is necessary to keep the shape of the bar of sugar from changing. The drying appliance is a compartment containing a moving apron, upon which the product is brought in contact with hot dry air. At the end of its journey it is projected upon several circular saws, where it is cut into bars of regular size, which are broken by a special apparatus. As the lumps obtained are more or less moist, they must be still further dried before being delivered to the consumer. The drying by means of hot dry air in this case, also, is effected upon aprons that have a backward and forward motion, giving to the lumps an irregular position on the band, thus making it impossible for the lumps to stick together. The lumps are subsequently placed in boxes and delivered to the trade. These machines can handle ten tons of sugar per diem, and the whole operation, from beginning to end, requires no skilled labor. While these continuous processes have certain evident advantages, they have not been as generally introduced as one would suppose. Experiments continue to be made, and it is thought that, before long, some practical solution of the problem will be reached.

Agglomerates.—In all the processes described in the foregoing the sugar is remelted, not necessarily with the idea of attaining a higher degree of purity than can be reached in a sugar factory, but to give the sugar crystals another shape and to cement them together. From the time of the early processes of sugar manufacture until to-day, numerous experiments have been made for the purpose of doing away with the remelting, which always ininvolves additional expense and certain sugar losses.

In 1864 FINKEN proposed in America that some method be used for compressing the massecuite into cakes. All the processes that have been suggested since then have a certain similarity. The sugar is moistened with water, or it is mixed with a white cleare to constitute a paste that can be blocked. Among numerous processes, mention may be made of the STEIN and CROSSFIELD [1] method,

[1] Oe.-U. Z., 28, 502, 1899.

in which sugar crystals are mixed with a saturated solution of sugar in a proportion determined upon in advance, so that the cakes or bars to be produced will have sufficient cohesion. This mass is forced by a vertical spiral into two openings in a table, in which there is an alternating compressor very much of the same design as that used in the manufacture of bricks. This motion is so ar-

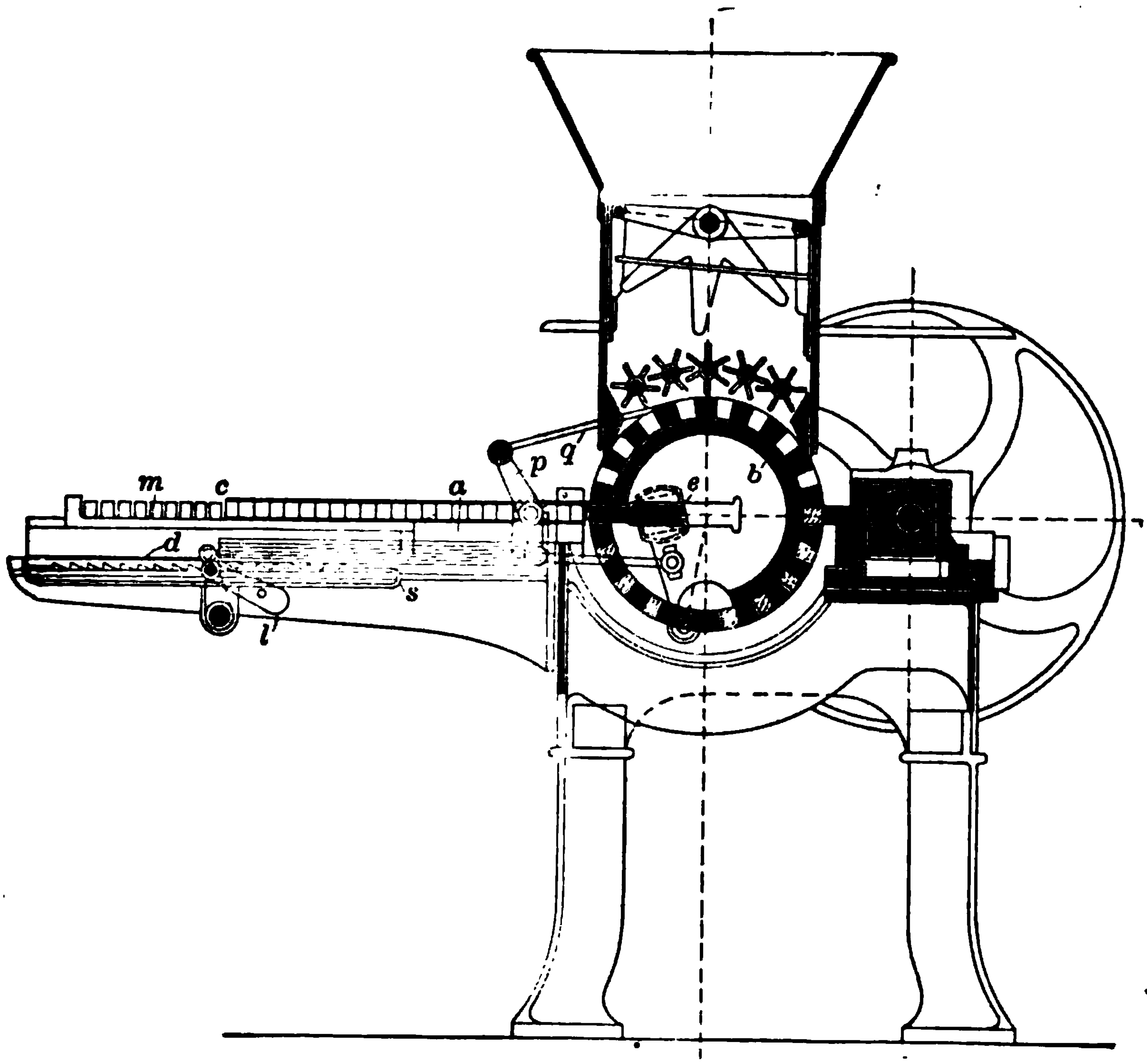

FIG. 203.—PZILLAS Press for Agglomerates.

ranged that, whenever there is a space under the distributing spiral, the other compartment, already filled with the mass, is under the plate, where it is submitted to a slight pressure. The cakes are mechanically removed from their moulds and dried, and are then either broken up into lumps or sawed into pieces of a specified size. This sugar has very much the appearance of the refined product.

Sugar agglomerates are never very homogeneous, and when when melted they leave irregular deposits that are not pleasing in appearance. Then, too, cohesion is lacking, and for this reason

they are not readily shipped. The following process is said to overcome the difficulty in a measure. PRANGEY[1] crushes the crystallized sugar into small lumps, but not into a powder, and uses for the purpose a VAPART crusher. This crushed mass is sifted, ventilated, and passed over a suitable bolter. The crushed sugar is mixed with a hot saturated cleare in a double-bottomed receptacle. There is produced a pasty mass at 70° to 90° C., which is poured into suitable moulds. This process consists in preparing a massecuite just as it done in the sugar refinery, but does away with the remelting. During the curing in the moulds, the sugar of the saturated mother liquor will crystallize and fasten the crystals together.

Among the presses for agglomerates that have met with some success, mention should be made of the PZILLAS (Fig. 203) apparatus. It consists of a mixer that distributes the crystal paste into openings of the drum, *b*. This drum revolves, and when it is in front of the piston, *e*, the moulded bars are pushed out onto the table, *m*, which, owing to a combination of levers, *s*, *l*, *p*, and *q*, advances a little more than the width of the bars. When the table is full it is taken to the dryer, and another one is put into place. In a more recent design by the same inventor, there is a horizontal moulding plate instead of a cylinder. One of the greatest difficulties in operating these compressors is the regulation of the intensity of the pressing, and the forward motion of the fresh lumps or bars.

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[1] Bull. Asso., **13**, 166, 1895.

CHAPTER IV.

SAWING, BREAKING, AND CRUSHING SUGAR.

Sawing.—For sugar sawing, saws of varied shape and size are used. As previously pointed out in the handling of loaf sugar, the loaves are cut in horizontal layers to obtain a series of rounds, but sawing sugar loaves is now fast becoming obsolete. The saws generally used for sugar cakes are circular, and several are placed side by side, their number depending upon the length of the cake. But in all cases the sawing involves only one operation and gives a series of bars, the width of which may be regulated by spacing the saws by means of washers placed upon their axis. For every change made in the saw spacing, a like change must be made in the guiding plate, or table, into which the saw penetrates. While the sugar is being cut it is firmly held in position, and the resulting bars are subsequently guided. In most cases the cakes are simply pushed against the saws by rods, but this method has the disadvantage of not being continuous in its working.

In the new type of saw of the Pzillas model this difficulty, like many others, is overcome. This saw will cut bars of different widths without the lower plates being placed under the saws. The spacing rings between the saws are changed to meet the demands of the market. The speed of the moving device for the bars is regulated by a differential pulley. In the Borssart saw, the forward movement is obtained by two grooved rollers, which, by means of springs, press the cakes against the saw. One of the rollers is worked by a suitable gearing, and the ultimate motion obtained is very regular. The cutting table has such a slant that the bars obtained simply slide down it.

Sugar sawing always makes a great quantity of dust. Many experts claim that there is some sugar destruction during the sawing caused by the heat generated. The amount of powdered sugar obtained during the cutting depends upon the width of the teeth

of the saw and the thickness of the bar to be cut. There are advantages in using the thinnest possible saws, but this idea must not be pushed too far, or the saw will not be strong enough to do the work. It is evident that the loss will be less if the cake is exactly as thick as the final sugar lump is wide, as the section cut per unit of lump is less. The manufacture of thin cakes for carrying out this idea offers certain difficulties—the curing is not so rapid and more labor is needed. On the other hand, the drying takes less time. The question must be decided for each special case.

Upon general principles, experience shows that the fewer the number of sawed sides of a lump of sugar the more acceptable it is to the consumer. The smooth, dirty-looking sawed surface contrasts unfavorably with the white crystal-like aspect of the natural surface. SCHEIBLER[1] proposed to overcome this difficulty regarding the appearance of sawed surfaces by simply projecting on them either a sugar solution, water, or steam, and allowing the syrup thus formed to crystallize.

Breaking.—When sugar is brought by a shock in contact with a cutting edge it is broken with ease, but, to obtain a more or less regular surface, two knives must be used at the same time on opposite sides of the bars. Precaution must be taken to have these knives almost exactly facing each other. The single blade appliances are rapidly becoming obsolete, as the dust accumulating upon the table that offers the resistance is a source of irregularity in the working.

The new SIELMANN[2] table has as many grooves as there are knives, these grooves being somewhat broader than the knives and widening at the bottom. To prevent an accumulation of powdered sugar between the lower knives, openings are placed at regular intervals at their lower extremities sufficiently wide to allow the sugar to escape; furthermore, there is a double slanting edge on the piece upon which all the lower knives are fastened, so that the powdered sugar more readily slides off through the opening left between them.

The VON NIESSEN[3] sugar breaker consists of an oblique table, over which slide, by gravity, the sugar bars that have been previously cut by circular saws. During their descending movement they are guided so as to enter the breaking apparatus, which has

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[1] Z., 52, 548, 1902. [2] Z., 51, 847, 1901. [3] Z., 51, 943, 1901.

two knives working in opposite directions and placed at the other extremity of the slanting table. The rods of the guiding device are all connected by an endless chain winding around two drums, one of which has an intermittent slow rotating motion which may be regulated by a ratchet-wheel receiving its movement through an excentric placed on the principal axis of the machine, and which has a connecting rod with the ratchet-wheel. This motion may be regulated by a very simple device, which allows lumps to be made of varied sizes, as the local market may demand. When the sugar bars leave the circular saws they are cleaned by suitable automatic brushes. The apparatus in its practical working is economical and labor-saving, as it does away with all carrying between the sawing and breaking.

Evidently the sawing causes more waste than the breaking, and hence every effort is made to do away with it altogether. The double knife-breaker of SCHEIFER, the first device of this kind used, continues to be much appreciated. It consists of a table having a backward and forward horizontal motion, which is effected by means of a ratchet-wheel (Fig. 204). The squares, *N*, receive

FIG. 204.—SCHEIFER Double Sugar-breaker.

the cakes of sugar and carry them towards *B*, where they are broken into bars. The position of the bars remains unchanged throughout their journey until the knives, *B′*, perpendicular to *B*, perform the final lump cutting. The knives, *B* and *B′*, are on a solid frame which raises and lowers them at the same time by means of a double lever working on the bearings, *Z*, *Z*. At the other end of this apparatus women collect the lumps and arrange them in boxes. This machine [1] is now constructed on the same principle, but with top and bottom knives cutting in one direction entirely independent of those cutting in the other, each having

[1] D. Z. I., 27, 1766, 1902.

a velocity of its own. Under these conditions it is possible to obtain lumps of any desired size, instead of the square lumps given by the original apparatus.

Owing to the fact that a considerable quantity of agglomerate sugar is sold, purchasers of lump sugars insist that the edges be rough. This has necessitated some changes in the manner of cutting the loaves. The GERLOFF[1] method consists in sawing these into disks about three times the thickness of the proposed lump, then, with a special breaking machine, the disks are split in two directions at right angles to each other, and each perpendicular to the direction of the sawing. The lumps thus obtained are again broken and have as a maximum one sawed surface, and at least one-third of the final lumps have rough surfaces and no sign whatever of the saw.

PESSÉ[2] has proposed to slice the sugar cakes fresh from centrifugals when they are still moist. The bars are placed on a table and pushed by a sliding motion towards the rotating cylinders; as new bars are cut they are pushed to the end of a small table, from whence the lumps are carried by a moving apron. As this travels faster than the lumps are deposited on its surface, there is a space between them. The lumps move through several heated rooms, and their moisture is thus eliminated in a very few minutes, instead of in several hours, as is required when drying the cakes. It is claimed that this rapid method of drying does away with colored spots on the surface, that are frequently noticed in cases where the bars remain too long in the ovens. It has been noticed, furthermore, that, when the bars are cut wet, the lumps have a brilliant appearance, while, when the cutting is done upon hard and dry bars, the friction of one crystal against another has a contrary effect, and their appearance is not so attractive to the eye.

Always with the view to economizing labor, efforts have been made to automatically arrange and pack the sugar. In Fig. 205 is shown the PIEPER classifier and packer. The bars are placed on the table, *a*, and made to move forward by the cog-wheel, *b*; they come under a double-cutting system of knives that receive their motion through *A*. One of the sides of the frame, *a*, is more or less movable, so that the sugar bars will not be jammed and wedged during the cutting action. After the lumps are obtained they continue to move on through the action of the cog-wheel, *f*, and fall into a wooden box, the top and bottom of which having been re-

[1] Z., 49, 744, 1899.

[2] Z., 50, 571, 1900.

moved, a temporary movable bottom, g, receives the row of sugar lumps. A lever, G, with counterpoids, presses all the row well into the box. The plate, g, is then lowered exactly the height of the lump. This motion is obtained through the wheel, H, the endless screw, s_1, and the rack, p. The contents of the box, I, is held in position by the counterpoise, i_1; but when the entire load has been filled it lets the plate, g, rest on the bottom, E. The box is then removed with its contents. The movable bottom, g, held in position by suitable angle irons, prevents the lumps of falling from the box. The latter is placed upon a table, boards are nailed on top, it is then turned over, and the real bottom is nailed on. During

FIG. 205.—I IEPER Classifier and Packer.

this interval a new plate, g, has been put in position, and the new box is being filled.

The cutting of the bars occasions some loss, caused by the crushed or broken edges, and, furthermore, a certain amount of irregular sugar is obtained. It is to be noticed that the regular lumps, with their angular edges, do not present the same aspect as the irregular ones, and, as this is not pleasing to the consumer, the irregular ones have to be separated. The yields obtained by the different methods of sawing, breaking, etc., are as follows:

YIELDS OBTAINED BY DIFFERENT METHODS OF SAWING.

Different products.	Loaves.	Vivien cakes.	Tiets cakes (Selwig and Lange).	Cakes Adant.
	(1) Per cent.	(1) Per cent.	(2) Per cent.	(3) Per cent.
Regular lumps............	55	75	71	83–88
Irregular lumps...........	30	18	19	3–4
Crushed and losses.........	15	7	10	9–7

[1] S. I., 26, 58, 1885. [2] BEAUDET, PELLET, and SAILLARD, Traité, 2, 99, 1894. [3] *Id.*, 102.

Crushing.—All the lumps and pieces which cannot be sold upon the market, either on account of their color, irregularity, or other defect, may be crushed and sold as powdered sugar. This crushing is done in various ways. The FESCA apparatus consists of a mixer, underneath which revolve in opposite directions two cast-iron cylinders, which are sufficiently near each other to crush these waste products satisfactorily. Special scraping devices upon the surface of the cylinder remove all adhering portions, but these must not be mixed with the powder. For another variety of this semi-powdered or crushed sugar a combination of cylinders is used, on the surface of one of which there is a regular, coarse roughness, and on the other a finer roughness to subsequently receive the semi-crushed wastes. The result is not exactly a powder, but a mass of irregular grains, crystals, etc., which is subsequently sifted. This form of sugar appears to have a ready sale in Italy.

CHAPTER V.

AFTER-PRODUCTS AND SUGAR LOSSES BY REFINING.

After-products.—It has been shown that, to obtain perfectly white sugar, it is essential to start with a massecuite of the highest possible purity. Under these conditions, the return to the pan of the green swing-out syrups from the centrifugal cannot be thought of, as there would be no heavier yield; on the contrary, the results would be inferior to those obtained without this addition. Some factories are even unwilling to introduce into the pan the comparatively pure swing-outs left after curing with a pure cleare.

Formerly the green syrup and the cleare swing-outs were used for the manufacture of second-grade refined sugar, known as bastards, lumps, etc. At present there is a general tendency to simplify the working of these special after-products. All the material that is sufficiently pure to exert no influence on the final sugar is introduced into the pan during the graining of the massecuite intended for refined, and what remains is grained as an after-product to be at once remelted. In this method of working, the most important point is to effect a complete separation of the after-products, under which conditions only a minimum quantity of non-sugar is returned to the pan.

For the after-product of an average and of a low purity, the processes are entirely different. MITTELSTAEDT[1] recommends that the refiner's after-products be classified into two principal divisions, those of a purity higher than 80 and those of less. The sugar from this after-product is dissolved in filtered water and mixed with superior swing-outs. The mixture is brought to 60° Brix, and after the addition of a small quantity of lime it is filtered and grained in pan. After the crystals are sufficiently formed, diluted, and filtered, the low-grade after-product is drawn into the pan.

[1] D. Z. I., **23**, 850, 1898.

The graining lasts for at least 10 hours. The massecuite is then sent to the crystallizators, where it is mixed for several days before being centrifugated. In most refineries one still finds the old crystallizing tanks for the after-products. Sometimes it is run into a series of small boxes of about two kilos capacity, but as this is very expensive it has been replaced by the crystallization in motion. In general, it may be said that there is very little difference in the methods of working after-products from refineries and the swing-outs in case of the manufacture of raw sugar. There remains a final molasses that is not quite of the same composition as that from raw sugar; but the difference is very slight, and sugar may be extracted from these residuums by exactly the same process.

Losses.—The extent of losses in the manufacture of white sugar continues to be a subject much discussed among experts, but an understanding cannot be reached, because these losses depend not only upon the care given during the varied manipulations, but also upon the process adopted in the production of white sugar. The working of a refinery in order to attain a complete exhaustion of the after-products is continuous and tedious; and, furthermore, there is considerable difficulty in keeping separate the different products at different periods of the working. Exact data relating to the subject is not readily obtained. WASILIEFF[1] claims that the loss of sugar in refineries is due to a decomposition during its storage, to changes during graining, and also to a decomposition during sawing. The most important of all are the mechanical losses in the massecuite moulds and those due to curing. They are greatest when making hard refined sugar.

LIPPMANN divides the losses during refining into two principal classifications: (1) The losses in substance, for one never obtains in finished refined sugar and molasses 100 per cent of the primitive substance; and (2) losses of polarization through the retrogression of the products, which means that the polarization of the finished product and that of the molasses does not give 100 per cent of the polarization of the raw sugar entering the refinery. The nature of the losses is sometimes mechanical and sometimes chemical. The mechanccal losses are due to the formation of scums in the cleares, losses in the boneblack filters, the adherence of sugar to the bags, the loss by theft of the workmen, and the slight excess in weight

[1] Z., 52, 957, 1902.

granted to the consumer. The chemical losses are due to sugar destruction.

Notwithstanding the fact that the extent of the losses is in a measure dependent upon the kind of raw sugar used and refined sugar made, and the perfection of the refiner's plant, allowing greater or less rapidity in the modes of extraction, it may be said that the loss in substance is 1 per cent and in sugar 1.33 per cent during the average working. The chemical losses during graining cannot be estimated. By the now obsolete processes, the refiners' products were grained so often that the volume of the massecuite worked during an average campaign weighed 5.5 times more than the raw sugar originally handled. At present this weight is 2 to 2.25 times that of the raw sugar entering the refinery, and the losses are considerably lessened. LIPPMANN very justly maintains that after each cooking of the juices there follows a loss of polarization that may vary from 0.3 to 0.5 per cent. However, there remains 0.3 per cent of unknown chemical losses. A portion of the sugar decomposes into furane, furfurol, acetone, and formic and acetic acid compounds. It is maintained that all these products may be formed, and yet the sugar is not necessarily inverted. The invert sugar estimation[1] would, consequently, lead to erroneous conclusions. The phenomena that take place are much more complicated and the sugar losses higher.

According to STADE,[2] during refining there is a known loss of 0.6 per cent and an unknown loss of 2 per cent. On the other hand, there is an increase in the percentage of non-organic sugar of 0.3 per cent. From this, one may conclude that at least a portion of the sugar is destroyed during refining. LIPPMANN[3] has noticed very much the same losses,—2.49 per cent for the total loss, of which 26.7 per cent is found in the char and the sweet water, while all the sugar lost could be found in the organic substances. This loss must be entirely attributed to the graining, and this increases with the impurity of the massecuite, the high alkalinity of the juices, the height of temperature during graining, and the duration of the strike.

D. Z. I., 28, 937, 1903.

[2] D. Z. I., 8, 823 and 846, 1883.

[3] Z., 31, 398, 1881; 33, 593, 1883; 34, 669, 1884; and 35, 407, 1885.

PART VIII.

UTILIZATION OF RESIDUES.

CHAPTER 1.

EXTRACTION OF SUGAR FROM MOLASSES BY OSMOSIS.

Melassigenic factors.—In theory, molasses is a final product of sugar manufacture, from which no more sugar can be extracted under the usual conditions of working and crystallization. According to CLAASSEN, the theoretical explanation of the inability of molasses to crystallize is that the non-sugar keeps the sugar in solution, and inversely the sugar holds the non-sugar in solution at all degrees of concentration and temperature.

DUBRUNFAUT attributed the non-crystallization of the sugar mainly to the salts which the residuum contains. His first argument was that one part of salts could prevent five parts of sugar from crystallizing, and after a long series of experiments he finally adopted the coefficient 3.73.

SCHUKOW[1] demonstrated by his experiments that the presence of salts and non-sugar in molasses increased the solubility of the sugar proportionately to the concentration and the temperature. This melassigenic action does not hold good for certain salts, such as calcium chlorid, until it reaches a special concentration, and for other salts, such as potassic nitrate, only when they are at a certain temperature. At 30° C. there will be less sugar dissolved in water containing this salt than there would be in pure water. The variations of organic substances with the same quantity of salts appear to have very little influence. Potassic sulphate and soda affect only in a slight degree the solubility of sugar.

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[1] Z., 50, 291, 1900.

According to HERZFELD,[1] the non-sugar of molasses contains lactic, acetic, formic, butyric, succinic, and fatty acids in considerable proportions, as well as lactic, succinic, valerianic, and butyric ethers and caramel. The quantity of acetic acid alone explains the presence in the molasses of so large a proportion of sugar that will not crystallize, allowing for the exceptional melassigenic power of potassium acetate. The quantity of lactic acid is such that it would possibly pay to extract it from this residuum. Then again the excessive viscosity of the concentrated after-product may be the cause of the non-crystallization. In this case the viscosity may be caused by an abnormal supersaturation of this residuum or by a low temperature. This may, in a measure, be corrected by increasing the temperature. Very often a crystallization might be obtained before the swing-out under consideration becomes a final product, but it is considered that the viscosity prolongs too much the time necessary for crystallization.

LIPPMANN[2] replies, to those who believe that viscosity is a melassigenic factor, that his numerous experiments have demonstrated that osmosed molasses has a higher viscosity than the residuum had before being submitted to this operation, and, notwithstanding this fact, it will readily crystallize, and the non-osmosed product will not. The whole question of molasses formation continues to be the subject of conjecture. It may be admitted that the lowest purity observed in a beet-sugar factory residuum molasses is 54 to 55. CLAASSEN points out that, even with exceptional care, the purity is 58 to 60, and in numerous factories it never gets lower than 60, and is generally very much higher. It would seem that molasses from juices of high purity should have high purities. With juices of a purity of less than 91 to 92, one obtains generally a molasses with a purity below 60, especially when, through extensive defecation, calcic salts are present, which decrease the solubility of the sugar.

The juices having the same purity, the molasses obtained at the beginning of the campaign have generally a lower purity than the residuum obtained at the end of the season. The nature of the non-sugar in this case, according to the authority last mentioned, plays an important rôle in molasses formation. The water percentage of molasses, obtained directly after being swung from the centrifugal, varies in most cases from 15 to 18 per cent. The following composition of a molasses may be taken as an example.

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[1] D. Z. I., 26, 1303, 1901. [2] D. Z. I., 23, 1288, 1898.

AVERAGE COMPOSITION OF MOLASSES.

Water	16.6	per cent
Sugar	50.1	"
Ash (after allowing for the carbonic acid)	10.8	"
Extractive substances (non-nitrogeneous)	11.5	"
Nitrogen	1.8	"
Total	100.0	"
Purity quotient	60.1	"
Saline quotient	4.64	"

The fact is, a large part of the product sold under the name of molasses is not in reality molasses. Either this residuum continues to contain crystallizable sugar, owing to the fact that the final crystallization was neglected, or that before or during the centrifugaling there was more sugar dissolved owing to the excessive use of water or steam during curing. The true definition of molasses is, that it is an after-product, from which no more sugar can be extracted by the ordinary methods of crystallization previously described. There remain other means of extracting sugar from molasses, and one of the oldest, and possibly one of the most reliable, is osmosis.

Theory of osmosis.—In 1826 Dutrochet[1] discovered the endomosis of liquids. The phenomenon may be explained in a few words. When two liquids that may be readily mixed are separated by a porous membrane, or diaphragm, there will be created a pressure on the surface by the molecules of the liquids, and this will tend to force them through the pores of the diaphragm from one side to the other in opposite directions. The size of the molecule appears to play an important rôle, for in one case there is a greater tendency to pass through than in another. Temperature, which affects the size of the pores and the activity of the molecules, also exerts an important influence. When one thus separates pure water from any solution of a substance, the osmotic pressure will force the water through into the solution, and the latter into the water. If the solution is made up of different substances, each of these will have a characteristic tendency of its own to work through the porous partition.

It has been noticed that, generally, substances with very simple molecules pass more readily than when the reverse is the case.

[1] Dubrunfaut, Osmose, 79, 1873.

Sugar being a substance with complicated molecules, its dialyzing powers are less than those of saline substances with which it is combined in the residuary molasses, for most of these are comparatively simple in their molecular structure. DUBRUNFAUT, who attributed to these salts a considerable melassigenic power, proposed to separate from the sugar of the molasses as much of the salts as possible, so as to allow other sugar molecules to crystallize. In his first experiments, which were most elementary in conception, but were later considerably improved upon, he suspended in water skins from which all fat had been removed and which were filled with molasses. The salts rapidly passed into the water through the porous membrane of the skin, together with a certain quantity of sugar, but in a smaller proportion than that in which they actually existed in the molasses. If the quantity of salts be very much greater, a relatively larger amount will pass through.

The molasses, more or less diluted, remains in the skin receptacle with a lower saline percentage. When this residuum is again concentrated up to a certain degree of supersaturation, it may, when cooling, allow an additional quantity of the sugar it contains to crystallize. This sugar may be separated by centrifugating, and the resulting swing-outs will be a new molasses, which may again be submitted to an osmose treatment, etc. However, there is a limit which cannot be exceeded, and this fact shows that it is not the salts alone that obstruct the crystallization of the sugar. For certain molasses this limit is reached after the second osmosis, and then again for other types of this residuum the operation may be advantageously repeated six or seven times. It is evident in theory that, by the lowering of the salt percentage, all the sugar should crystallize little by little. In practice it is found that, after a certain limit is attained, the percentage of organic non-sugar that osmoses with greater difficulty than the sugar will increase and exert its influence in forming an obstacle to the crystallization of the sugar, and this occurs to a far greater extent than is generally supposed. Consequently, from what has been said, it may be seen that the practical application of osmose has definite limits which cannot be exceeded.

Dubrunfaut's osmogene.—The skin bags used for these preliminary experiments were only points of departure for something more practicable. The appliances next used were variations of the filter press. Between two large cast-iron disks, one stationary and the other movable, are pressed a series of wooden frames. These

are of two kinds (Figs. 206 and 207). They have four round holes, *A*, *B*, *C*, *D*, or *A′*, *B′*, *C′*, *D′*. Between the frames are pressed sheets of parchment paper, with four perforations. The apparatus known as osmogene consists of a series of small compartments with a comparatively large porous surface between them. One-half of these compartments is filled with molasses and the other half with water, the circulation of the two liquids being in the opposite direction. Water is introduced into the frame at *A* (Fig. 206), and flows into the passage, *a*, through the thickness of the wood, and into the interior of the frame. After spreading itself over the entire surface of the parchment paper, and receiving some of the salts from the molasses

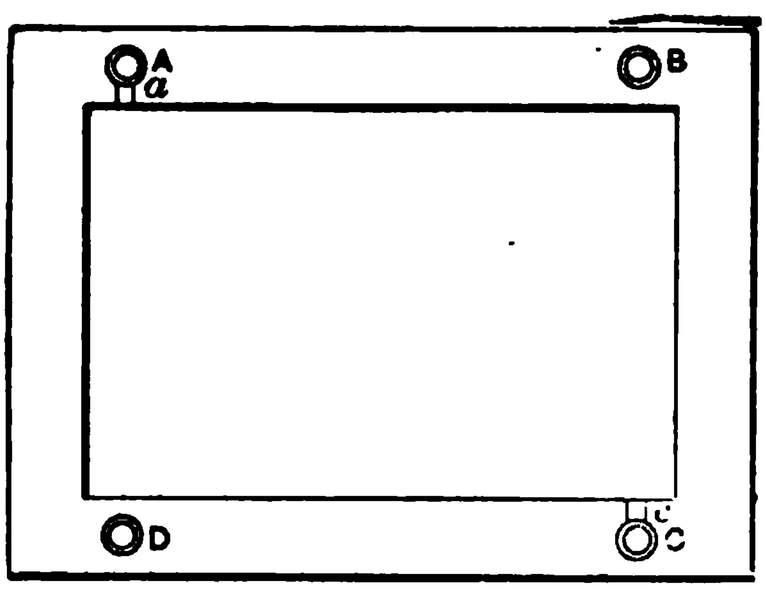

FIG. 206.—DUBRUNFAUT Water-frame.

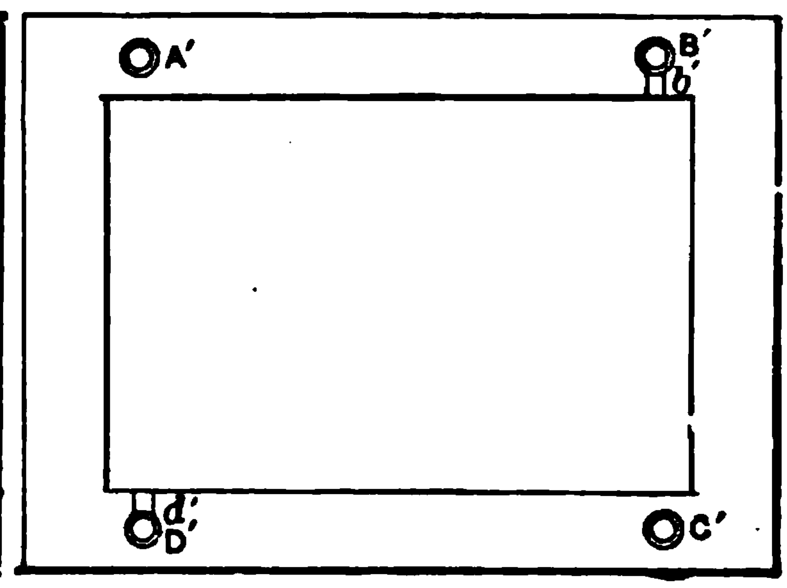

FIG. 207.—DUBRUNFAUT Molasses-frame.

on the other side, this water of exosmosis passes through the passage, *c*, into *C*, and leaves the apparatus.

The molasses enters the molasses-frame (Fig. 207) by the passage, *D′*, then flows by *d′* into the interior of the frame and spreads itself over the surface of the parchment paper, so as to allow the saline substances to pass through into the water on the other side. After having undergone this epuration by osmosis, and become somewhat diluted with water from the water-frame, the residuum rises to the diagonal corner, passes through *b′* into the passage, *B′*, and out of the apparatus.

These frames present certain serious disadvantages regarding the logical circulation of the liquids and the rational utilization of the porous surfaces. The natural tendency of the circulating liquids would be to move in a direct line from the entrance to the exit openings, from *A* to *C* on the one hand, and *D′* to *B′* on the other, without a renewal of the liquid in the other corners of the frames. This observation led the inventor to make some important changes in the arrangement of the frames. In Fig. 208 is shown a

frame in which the liquid entering at *c* passes by *e* into the interior of the frame, and is compelled to follow a horizontal zigzag road before reaching the exit opening, *e*. On each of these baffle divisions are holes, *f*, which permit the liquid to escape from one to

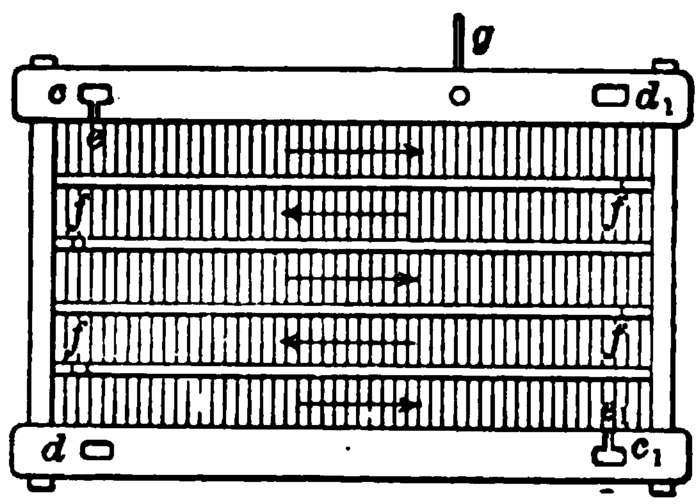

FIG. 208.—Frame with Zigzag Circulation.

the other. The small pipe, *g*, indicates the level of the liquid in the water-frames, and serves also as an air-vent during the filling with water. In most of these osmogenes the water-frames may be used for molasses, and the molasses frames for water, should there be a

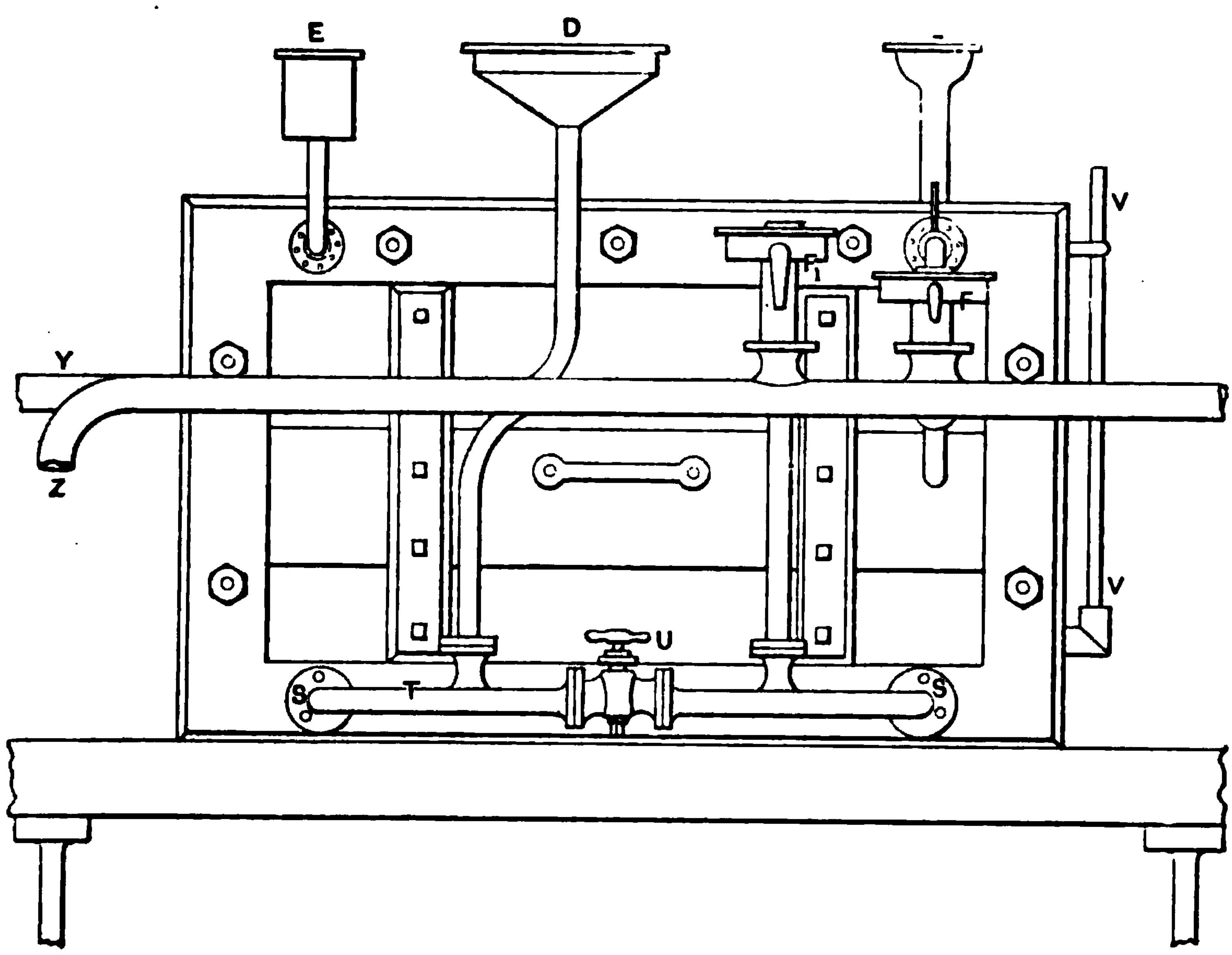

FIG. 209.—End View of DUBRUNFAUT Osmogene.

need for this change. This feature is an advantage, as will be subsequently shown.

In Fig. 209 is an end view of the DUBRUNFAUT osmogene, which

differs from the apparatus just described in certain details. The molasses is distributed through the funnel, *D*, and the water enters at *E*. The air vent is shown at *L*; *V V* is the pressure gauge and water level. The exosmose water and osmosed molasses leave the apparatus through the test jars, *F* and F_1', in which are placed suitable hydrometers, so that the working of the osmogene may be under constant control. The cock, *U*, permits a communication between the molasses- and water-frames by means of the pipes, *S* and *S*. When the apparatus is working under normal conditions, these passages are closed. These osmogenes may consist of 50 to 150 frames, and have 22 to 65 sq. m. of osmosing surface. An osmogene[1] of 50 frames is sufficient for the handling of 1200 to 1250 kilos of molasses per diem, and an apparatus with 100 frames has a capacity of 3000 kilos of molasses in twenty-four hours.

Parchment paper.—When the principle of osmosis was first introduced, it was customary to use real parchment, and, if parchment paper had not become a cheaper substitute, the osmogene now still in vogue would long since have become obsolete. The parchment paper invented by Poumarede and Figuier is obtained by submerging a glazed paper for 30 seconds in a cold-diluted 65 per cent solution of sulphuric acid. The paper is subsequently washed with cold water, then with ammoniacal water, and finally in fresh water. This paper when dried has all the appearance and important characteristics of real parchment.

Neumann, who was the first to manufacture this paper on a practical scale, found numerous difficulties in obtaining a homogeneous and regular product, as the acid impregnation was very irregular, and consequently the paper could not be used for the purpose intended. The proportions that had not been attacked by the acid did not possess the desired porosity, and the liquid, instead of diffusing at those centres, simply filters or runs through, finally making holes on the surface. Little by little these difficulties were overcome, and the product now on the market is absolutely homogeneous. It is interesting to note that this osmogene paper[2] has five times the resisting power possessed by ordinary paper, and has two-thirds the resistance of real parchment.

Before these sheets of parchment paper are placed on their respective frames, they should be carefully examined. Spots indicate certain faults, and all torn sheets should be thrown aside.

[1] Leplay, Osmose, p. 79, 1883. [2] *Ibid.*, p. 34, 1883.

The duration of the paper and results obtained depend not only upon the paper, but also upon the molasses being osmosed. After an interval of about three to six days, it will be noticed that the paper has lost all consistence, and that under the slightest traction it will fall to pieces. It is possible to follow the deterioration of the paper by the increased coloration of the exosmosed water, and, furthermore, the density increases, all other conditions remaining unchanged. This increase is regular, and a sudden change is possible only through the rupture of the osmosing medium, which rarely occurs.

The average life of parchment paper is one week. The leading experts declare that the alteration of the paper is due to the existence of a caustic soda alkalinity, but when the alkalinity comes from carbonate of soda there is no alteration. Furthermore, there is necessarily a mechanical action, caused by the friction of molecules, that must not be overlooked. There are also mechancal impurities of the liquids, which tend to soil the paper and fill up its pores. Hence it has always been insisted that a thorough filtration of the molasses and the water were among the essentials for satisfactory osmosing. Certain precautionary measures have been taken to protect the paper, which are described under another heading.

Conditions needed for osmosis.—When the methods of osmosis were first introduced, the results obtained were only moderately encouraging, but several years later the experts began to realize what the essential conditions for success were. It was noticed that heat was favorable for osmosis, and experience showed that the operation should be conducted at a temperature as near as possible to 100° C., and under no circumstances should the molasses being osmosed be allowed to fall below 70° C., for then the osmotic action very materially diminishes, and the salt separation desired consequently becomes less.

As previously pointed out, it is most difficult to decide up to what limit the omosing should continue; for this depends upon the purchase price of molasses, the selling price of sugar, and the cost of fuel. The further the osmosing continues, the greater will be the volume of water to be ultimately evaporated; and to obtain the desired concentration that would allow crystallization, the osmosing may, consequently, be light or excessive. By the latter the specific weight of the residuum treated may be brought to 15° Bé., while by the former it does not fall much below 25° Bé. Furthermore, the exosmose-water contains more sugar. According to

DUBRUNFAUT,[1] through a light osmosing, when the specific gravity of the osmosed molasses is kept between the limits of 25° and 30° Bé., one-quarter of the salts is eliminated. It was claimed that 10 to 12 per cent of the sugar could then be extracted. The fact is, the osmosing limit should be determined for each factory.

Working of osmogenes.—The working of an osmogene presents certain characteristics, but no difficulty whatsoever, with few or no perturbations, and thus from start to finish it is generally satisfactory, and requires but very little attention. In starting the apparatus it should be first filled with warm water to heat it, then emptied, and water and molasses simultaneously introduced into their respective frames. The filling of the water and molasses frames should be done in pairs as the operation progresses, so as to avoid the difference of pressure on either side of the parchment paper. When the osmogene is full, the entrance flow of the liquids is so regulated as to obtain the desired conditions determined upon in advance at the exit flow. Some recommend that all the molasses-frames be filled with hot water before introducing the molasses; but this procedure does not give sufficient regularity in the general working, and, furthermore, the operation is delayed, and the sugar losses during starting are considerably increased.

To properly regulate the inward flow of the molasses, the residuum should be heated to a regular temperature, for the reason that the viscosity of the molasses varies very considerably with the temperature, and that very variable volumes of molasses could be introduced for the same opening of the regulating cock. It is necessary that the molasses be free from all mechanical impurities, so as not to obstruct the regulating cock, which has a position depending upon the density of the osmosed molasses and the ex-osmose-water. In the jars through which the liquids circulate upon leaving the apparatus are hydrometers graduated especially for the temperatures at which the liquids are to be maintained. It is to be noted that the glass of the hydrometers, by being continuously in contact with molasses, will dissolve, and thus give, after some time, a very misleading indication. The alteration takes place at the point where is formed the meniscus, and there frequently follows a cracking at that spot. LANDES[2] uses spindles with a metallic upper portion. Should any difference be noticeable in the reading, the hydrometer is adjusted by a few shot.

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[1] S. I., 6, 307, 1872. [2] Oe.-U. Z., 27, 381, 1898.

When the density of the osmosed molasses falls below the limit determined upon in advance, the entrance flow of the molasses into the osmogene is increased, or is diminished when the exit density of the osmosed fluid is too high. On the other hand, if the density of the exosmose-water is too high, the entrance flow is increased, and if the density in question is too low it is diminished. For very light osmosing, the entrance of water and molasses is so regulated that the osmosed molasses will indicate 35° Brix., and the exosmosed water 3° Brix. The regulation of these densities may be accomplished by any person, even after a limited experience, and several appliances can be regulated at the same time. However, as the man in charge is not always dependable, a number of automatic self-regulating devices have been invented and tried. The most rational ones are governed by the densities of the liquids leaving the apparatus. On the other hand, another combination is regulated by the molasses and water as they enter the osmogene. Very few of these devices have received practical application.

Notwithstanding all the care that may be taken to eliminate the mechanical impurities from water and molasses, it is impossible to prevent deposits upon the surface of the paper. These are removed by daily hot-water washing of the osmogene, and also the direction of the circulating liquids is changed after regular intervals of two to three days, that is to say, the molasses-frames are used for the water, and inversely the water-frames for molasses.

Graining of osmosed molasses.—The osmosed molasses is grained to string proof in pan. Sometimes difficulties occur during graining, and no explanation has been offered as to the exact cause. The alkalinity,[1] neutrality, and acidity apparently have very little influence on this phenomenon. After this operation is completed, the product is sent to the crystallizing tanks, and, by recent methods of working, it is handled in the crystallizators in motion. Experience shows that in the tanks the crystallization is slow. The rooms in which these receptacles are placed are heated to a high temperature, and it is at least four weeks before the product is ready to be centrifugaled.

The final sugar obtained has a much darker color than ordinary raw sugar from after-products, as the coloring substances, having a complex molecule, remain with the sugar in the osmosed molasses. For the same reason, these sugars contain very little

[1] D. Z. I., 5, 710, 1880.

ash and a high percentage of organic substances. The osmosed sugar is difficult to sell upon the European market, and for that reason the general tendency is now to resort to remelting, and a subsequent combination with the beet syrups during their working at the factory. The swing-out syrups from these sugars is again osmosed several consecutive treatments. Under these conditions it is possible to obtain from 25 to 30 per cent of the sugar contained in the molasses, and, under specially favorable conditions of working, that amount has been exceeded. The final residuary molasses is of an inferior quality, either for distilling or other purposes, such as desugarization by strontia, for example. This inferiority, according to some experts, is due to the low percentage of salts.

Modifications in osmosis and osmogene.—Numerous modifications have been proposed for the working by osmosis. The earliest of these was the DUBRUNFAUT calcic osmosis, in which the after-products from "firsts" were combined with 10 per cent of milk of lime at 20° Bé. before osmosing. This process did not meet with success.

Many arrangements and devices have been proposed and adopted for holding the parchment paper in the frames, and for overcoming the rupture of the paper during the filling of frames. The early method consisted in stretching a series of strings in the frames on both sides of the parchment, but these strings, not being all equally stretched, would break, and so did not overcome the difficulty. Instead of strings, strips of wood were then used, but these rendered the construction of the frame extremely complicated.

SELWIG and LANGE[1] made frames with brass wires stretched lengthwise and twisted in spirals, and introduced at the same time another modification in the osmogene, permitting the current of the circulating liquids to be reversed by the use of a single cock. A considerable economy of manual labor was thereby accomplished as compared to that needed for many of the osmogenes now in use. The arrangement of the passages for the water and molasses have many special features. Another form of frame for the osmogene as made in Germany consists of an inside wire network turned in elliptical spirals. The arrangement is such as to give the parchment paper a support over its entire surface, which prevents two adjoining paper divisions from coming in contact. It is claimed

[1] La. S. B., 11, 202, 1883.

that both the molasses and the water circulation are then perfect,[1] while at the same time the escape of the air in the frames is greatly facilitated.

Loew[2] suggested the use of a porous paper on both sides of the parchment to hold it, and help it to resist the action of the mechanical impurities, which, he states, cause it to be very readily broken. Under these conditions, the foreign substances are held back, and the life of the parchment paper is, consequently, 19 instead of 7 days. The Mathée and Scheibler method of preventing the wear of the parchment paper, which is always greatest on top of the osmogene, consists in building the apparatus on a pivot, which allows the osmogene to be turned upside down. In this way the lower portions of the paper, which are generally in an excellent state of preservation, may be used on top until worn out, as the last sheets in this way become the first. From data coming under the writer's notice, it may be concluded that the life of the parchment paper is considerably prolonged by this arrangement.

The Daix improvement is also very important. The general flow of the molasses and water is indicated in Figs. 210 and 211.

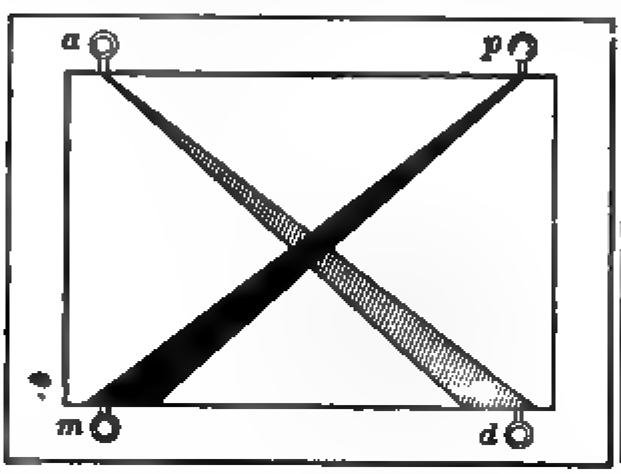

Fig. 210.—Flow of Molasses and Water in an Ordinary Frame.

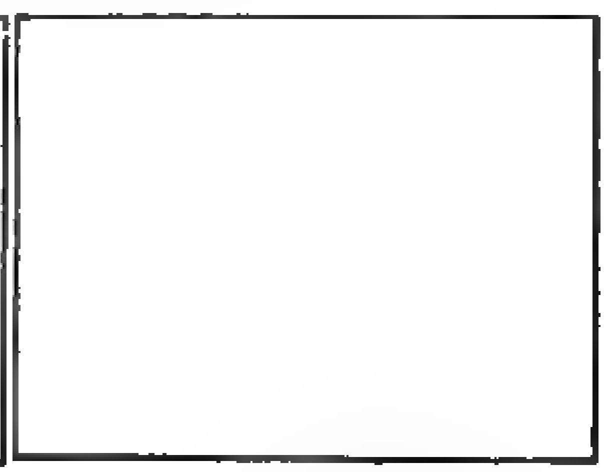

Fig. 211.—Flow of Molasses and Water in a Frame with Baffle Partitions.

In both cases, the water enters by *a* and escapes through *d*, while the molasses enters at *m* and leaves at *p*. The width of the lines is proportionate to the amount of salts contained in the water and the molasses. At *a* the water is pure, but as it passes through the frame it becomes more and more saturated with salts, as is shown by the shading. On the contrary, the molasses represented in block contains more salts at the commencement than at the end of its journey, its escape being at *p*. In order that the flow

[1] Z., 50, 775, 1900.

[2] Oe.-U. Z., 11, 64, 1882.

may be in every respect satisfactory, the currents should correspond to each other; that is to say, it is essential that the purest water and the most osmosed molasses be opposite each other on different sides of the parchment paper, and, as the water becomes more and more charged with salts, it should meet molasses that is more and more saline. This is shown in the frames of the DAIX combination in Fig. 212, the exit, *p*, of the osmosed molasses being

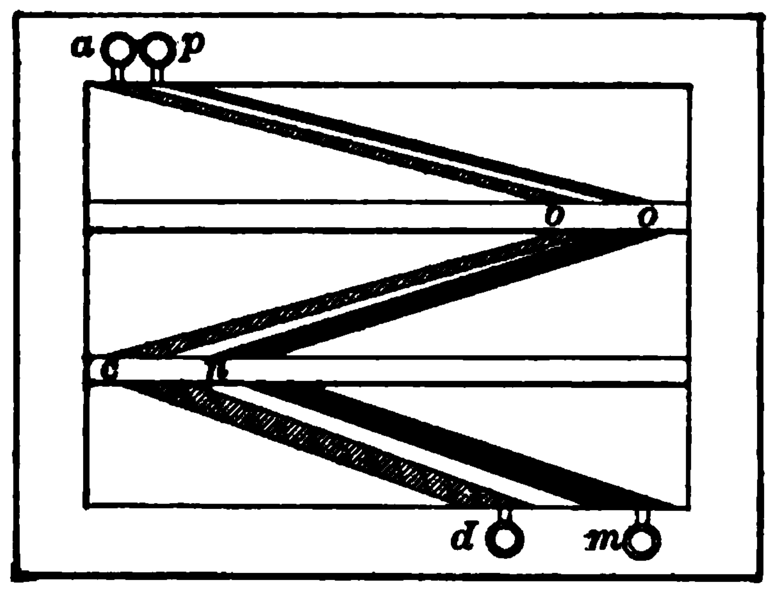

FIG. 212.—Flow of Molasses and Water in DAIX Rational Frame.

alongside of the entrance of the water, *a*, and the entrance of the molasses, *m*, beside the exit, *d*, of the exosmose-water. Under these conditions, the rational currents asked for are realized. The lines representing the currents have proportional widths.

Another characteristic fault of the ordinary osmogene is the want of proportion between the section of the entrance to the frame and the section of the distributing pipe. This causes an irregularity in the efficiency of the different frames. To overcome

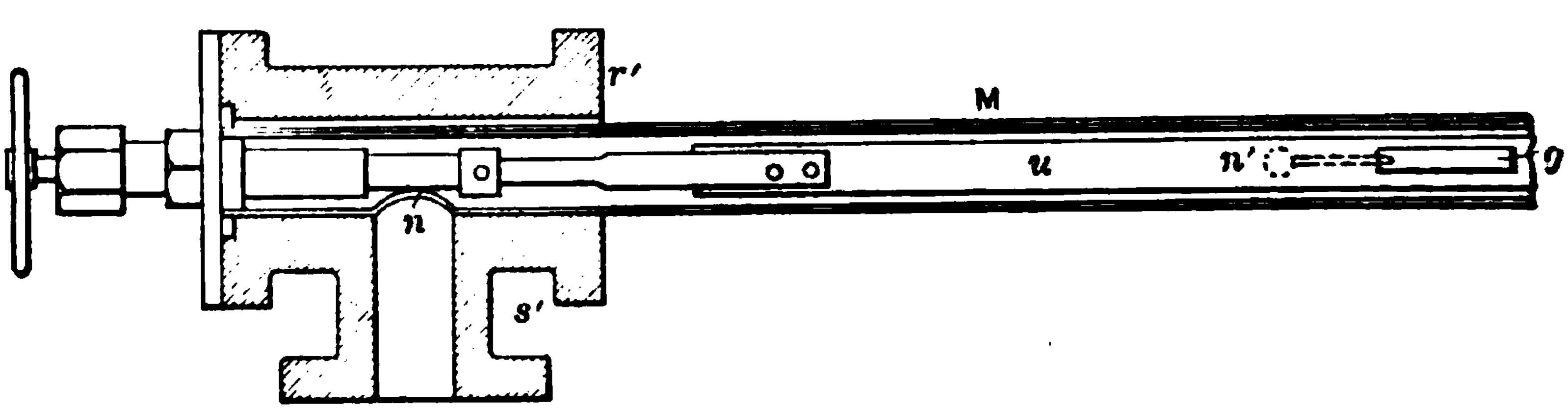

FIG. 213.—WANIECK Molasses Distributor.

this difficulty, SELWIG and LANGE had a system of special passages, which brought the circulation from back to front. The DAIX[1] method of overcoming the difficulty is to give different diameters to the openings of the different frames. In order to regulate the entrance flow of the molasses in the WANIECK[2] osmogene (Fig.

[1] J. d. f. d. s., 25, 11, 1884.

[2] Z., 51, 69, 1901.

213), there is placed in the holes of the frames for molasses a pipe, *M*, with slits, *n'*, corresponding to the openings of the frames. Into the pipe may be slid a rod, *v*, having the same opening as the pipe, whereby the two slits correspond to each other, and, by moving the rod backwards or forwards, one may regulate the size of the slit.

From the point of view that the quantity of salt eliminated from the molasses is always in given proportions, LEPLAY proposed an osmogen to serve the double purpose of osmosing on the one hand and evaporating on the other (Fig. 214). All the frames

FIG. 214.—LEPLAY'S Osmogene Evaporator.

of this apparatus are open on top and communicate with the box, *A*, forming the upper part of all the frames. In this portion there is a steam coil, *B*, which will evaporate the osmosed molasses as fast as it escapes from the respective frames.

FUCHS [1] introduced several interesting changes in his osmogene which appears to have met with some success (Fig. 215). It consists of large pentagonal frames, with the point placed downward, and held together by the tightening of the press screw. The osmogene paper of these frames occupies a square space, leaving free at the lower portion a triangle separated from the frame by a horizontal lath, and divided in two by a vertical lath. One of these two divisions, D_1, is used for the circulation of the molasses, and the other, D^2, for hot water. The frames for the molasses and for the

[1] Oe.-U. Z., **30**, 271, 1901.

hot water alternate in the press, and are alternately put into communication with the triangular canal, D^1, for the molasses, or with the water canal, D_2, by the aid of small vertical holes, a, a_1, a_2, a_3, a_4, made in the thickness of the wooden frame. The frames have also at their upper part holes, b, b^1, b^2, b^3, and b^4, allowing the exosmose-water to run off from the water-frames, and permitting the exit of the osmosed molasses from the molasses-frame. The

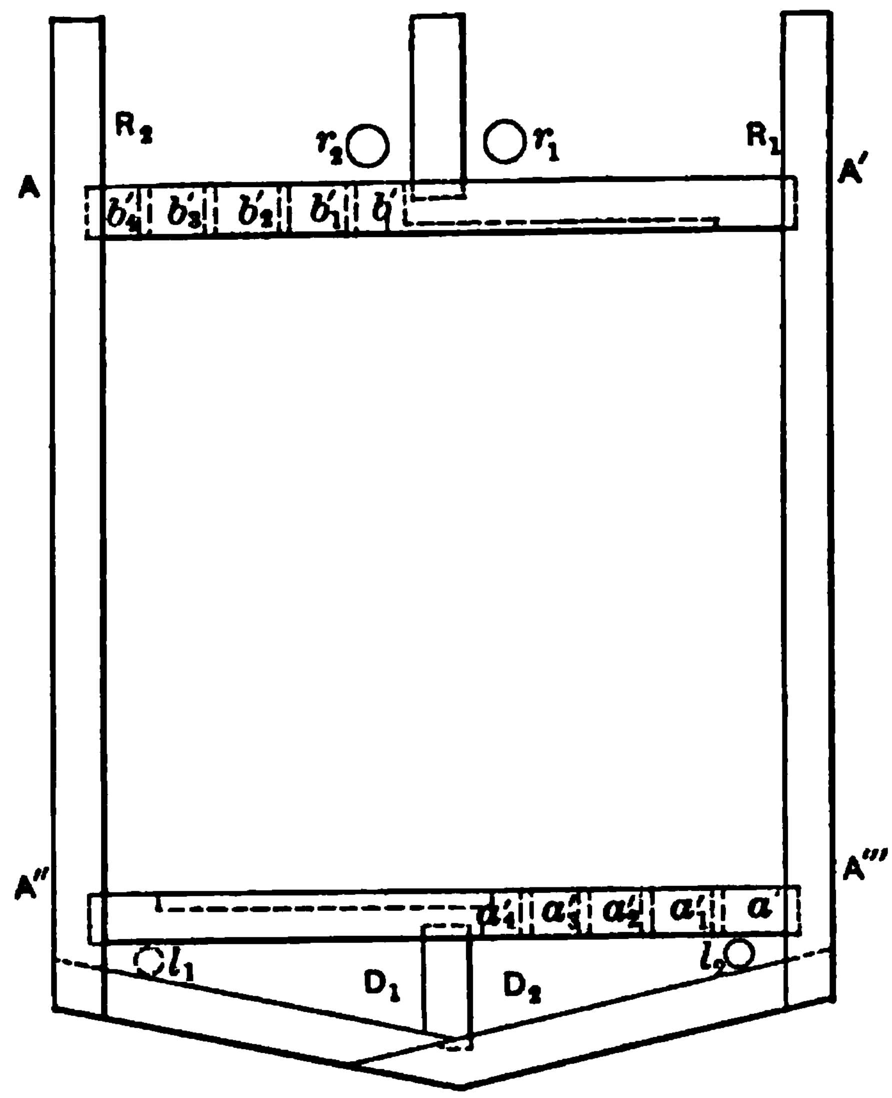

Fig. 215.—Fuchs Osmogene Frame.

liquids are run into two jars containing hydrometers, and which, according to the density of the liquids, open and close upon the arrival of the molasses or hot water in the frames. The apparatus is automatic in its working. The fact that none of the joints proper is perforated is one of the advantages claimed, as a perfectly hermetically closed frame is thus obtained. By a proper combination of frames, it is possible to completely change the direction of the circulation by turning a special cock. The exit cocks must be reversed at the same time. These changes, however, should be preceded by a washing of the frames with hot water until the water runs off pure. The apparatus may be used as a filter press by substituting for the parchment paper some filtering material without holes. The efficiency is all that could be desired. Some practical comparative experiments[1] made with the Fuchs osmogene

[1] Saillard, Technologie, 190, 1904.

have shown that it has great advantages over most of the other types used.

Utilization of exosmosed water.—Numerous plans have been proposed for the utilization of the exosmosed water. When these appliances were first introduced, it was customary to allow the water to escape into an adjoining stream, but this resulted in numerous litigations. To overcome the difficulty, the water was run onto the farm lands near the factory. There are various processes for its concentration, with the view of obtaining the salts, which are valuable for fertilizing purposes, and also for its fermentation in order to obtain alcohol from the sugar contained therein. The draining upon the lands demanded very extended areas, which were not always available; furthermore, the soil had to be reasonably porous, so that the salts brought by the residuary water would not be retained by the surface soil. From an economical point of view, where the mode was practicable, it was most advantageous, as most of the plant foods were returned, and the fertility of the land was thus maintained. The evaporation of this exosmosed water is a very expensive method of obtaining its salts, unless fuel is cheap, as such waters rarely contain more than 5 per cent of dry matter. However, for many years the salts were industrially extracted from these waters in a crystallized form. Saltpeter and chlorid of potassium were obtained, but the low market price of these chemicals led to the abandonment of the industry.

It is interesting to note[1] that, when the water is used as a fertilizer, it should be applied in the winter, under which circumstances the organic substances contained in the residuum undergo certain changes before the time of planting arrives. This does away with any possible objectionable influence of the organic compounds upon the sugar quality of the beets. When concentrated osmose-waters are employed, certain precautionary measures should be taken, such as an ample distribution of lime upon the surface of the soil, as when potassic salts are used.

The utilization of exosmose-waters for distilling purposes presented grave difficulties for many years. It was proposed, and tried, that the final osmosed molasses be combined with the exosmosed water. Fermentation was not active, even with the use of a superior ferment. As regards the extraction of sugar by another osmosing, as previously pointed out, the problem is again reduced to the question of expense of evaporation

[1] S. B., April, 1902.

CHAPTER II.

ELUTION.

General considerations.—Previous mention has been made of the combinations of sugar and lime, some of which are insoluble under determined conditions. Supposing that a certain portion of the foreign substances remains in the solution, their separation may be effected through simple filtration. Since PELIGOT'S first investigations in 1838, relating to saccharates of lime, numerous experiments have been made to give the phenomenon discovered some industrial application. In 1862 an elution patent was refused to SCHEIBLER, that is to say, a patent of a process based upon the formation of an insoluble saccharate in alcohol and the washing of this saccharate to separate foreign substances. The saccharate obtained was subsequently decomposed through the action of carbonic acid into carbonate of lime and sugar.

Scheibler process.—SCHEIBLER discovered that lime saccharate and alkaline oxids are gelatinous when precipitated, and become granular when dried. Consequently, the washing of the product offers no difficulty. The process under consideration consisted in adding recently slaked lime to molasses in such a way as to have one molecule of sugar correspond to three molecules of hydrated lime. The semi-fluid mass thus obtained becomes compact when cooled, but is difficult to wash. The temperature was gradually raised to 100° C., and the drying was done at that temperature. The mass thus obtained was very friable. It was placed in large iron receptacles, not unlike the diffusors of a diffusion battery, but called elutors, in which alcohol at 35 per cent in volume was used for washing.

Finally, there remained a saccharate, more or less pure, which was used during defecation instead of lime. During carbonatation, the sugar was liberated and continued to be handled at every stage of the factory's working. The solutions still containing impurities

were submitted to a distillation, in order to recover the alcohol that would otherwise be lost. The final residuary product consisted of the impurities in question and a certain quantity of saccharate of lime. This process, however, had some serious disadvantages. Considerable sugar losses occurred in the washing liquid, and the defecation of large quantities of lime saccharate was most difficult.

Seyfert-Scheibler process.—In 1872 SEYFERT proposed that, instead of hydrated lime, quicklime be used. This lime, when slaked by coming in contact with the water of the molasses, evolves sufficient heat to liberate most of the remaining water in the form of steam. The steam bubbles thus formed create cavities in the mass of the saccharate, and thus render it very porous, and especially adapted for the removal of foreign impurities through an alcoholic washing. Furthermore the liberated heat was sufficient to completely dry the mass, and thus bring the saccharate to a satisfactory granulated condition.

Into an apparatus very like that used for the manufacture of mortar, consisting of two vertical grinders, a given quantity of molasses and lime was introduced. There followed a complete crushing, and during this period horizontal scrapers collected the resulting paste, so that the mixture might be more homogeneous. The apparatus is emptied at the bottom into small receptacles, in which the saccharate solidifies. It is subsequently broken into large lumps, and then, by means of a knife revolving machine. into smaller lumps about 1 to 2 cm. in size. The machine should make the least possible powder, so that the elutors will not become clogged. The knives of the apparatus are held on two parallel axes, and have six teeth each. This mass is submitted to elution, as in the previous SCHEIBLER process, and the saccharate is used during carbonatation.

The process, as introduced by BODENBENDER at the NORDSTEMMEN (Fig. 216), Germany, factory, handling 17,000 to 18,000 kilos of molasses per diem, is as follows: The lime-molasses combination is prepared in a mixing and crushing apparatus, consisting of a conical hopper, *E*, of 2.300 m. in diameter on top and of 0.5 m. at the bottom, leading to a crusher, *A*, with rolls 1.2 m. in diameter, revolving at a rate of 10 to 12 revolutions a minute. In this crusher, 150 litres of water at 75° C. are run from the tank, *B*, then 350 kilos of fresh molasses from *C*, and then 108 kilos of lime in powder are added from the hopper, *E*, and measured in the apparatus, *D*

This has six sections, holding 18 ki os each. The mixing lasts 15 minutes. The ultimate product is a pasty mixture, having a slightly yellow color, and is sufficiently fluid to escape into a side tank.

The quantity of water and pulverized lime used depends upon the volume of molasses. The quantity of molassate run into the tank should be sufficient to produce cakes of a determined dimension. These are divided in two, and each half weighs about 50 kilos. These tanks are placed one over the other in the room where the crushing and mixing apparatus is located. After 24 hours the molassate is solid, and it is then taken to *F*, where it is sliced into strips 15 mm. wide and 2 mm. in thickness. The slices are collected in a hopper, and then distributed into cars, from which the

FIG. 216.—Schema of the SEYFERT-SCHEIBLER Process as Adopted by BODENBENDER.

elutors, *G*, are filled. At the NORDSTEMMEN factory the slicer is placed on the second floor.

Each elutor consists of a sheet-iron cylinder, having a screen and a steam coil on the bottom. There are 16 elutors, placed in two rows of 8 each, having a total capacity of 15,000 litres and holding 11,400 kilos of molassate. Of the 16 elutors of which the battery consists, only 12 are in full activity, as the remaining four are either being filled, emptied, or cleaned. If we consider, for example, the 12th of the series as the one recently filled, pure alcohol at 40° is introduced from the bottom, which has the object of eliminating

the principal impurities from the molassate. After 24 hours the alcohol is removed and sent to the rectifier. The alcohol drawn off is replaced by the alcohol from the preceding elutor of the battery, and then connection is made with the series. The rotation continues and finally, instead of being the last, number 12 becomes the first. At this moment it receives pure alcohol for the progressive washing just mentioned. The complete operation takes 134 hours.

The elutor, having had its contents sufficiently washed, is ready to be emptied. The washed slices retain a certain quantity of alcohol, and are heated by means of the steam coil from the bottom, this operation lasting 8 hours, the alcoholic vapors being collected and sent to the rectifier. The milk of the saccharate is sent to two waiting receptacles, *H*, of 12,600 litres capacity, which communicate with two smaller jars, *I*, containing suitable mixers. The pump, *J*, draws off this liquid lime saccharate, and sends it to the carbonatation tanks.

There are three sorts of alcohol obtained during elution,—the alcohol of the first washing in the tail end of the series (the number 12 mentioned above), that from the battery when in full activity, and that obtained through the distillation of the liquid saccharate of lime. These three sorts of alcohol are collected in special tanks, and are then rectified. The rectified alcohol is sent into three horizontal reservoirs of 7300 litres capacity, and additional alcohol to make up for the losses, and sufficient water to bring the liquid to 40 per cent in volume, are added.

The Manoury process has certain characteristic features in the preparation of the lime molassate (Fig. 217). Baskets full of quicklime are submerged in the tank, *A*, filled with water, and are then withdrawn, small piles being made of the moistened lime thus obtained. The lime slakes and falls to a powder. This operation offers no difficulty if the limestone is sufficiently porous; but if it is compact, the water sprinkling must be repeated several times before the desired results will be obtained. The hydrated lime powder is raised by the band carrier, *B*, and emptied into a hopper communicating with the sifter, *C*, in which the non-slaked portions are separated. The unslaked lime is again sprinkled with water. The hydrated lime falls down a slanting distributor into the measurer, *D*. Molasses is brought from the tank, *F*, passes through another measurer, not shown in the drawing, and comes in contact with the lime in a special mixer, *E*, consisting of a horizontal cast-

iron drum, inside of which there are curved, agitating arms. A suitable valve permits the regulation of the quantity of lime introduced from the measurer, *D*. There are two other upper openings, one for the escape of air and the other for the introduction of the molasses.

This apparatus is called a granulator. Into it may be introduced, for example, 150 kilos of powdered hydrated lime, then 100 kilos of molasses at 42° Bé., to which 2 to 3 per cent carbonate of soda has previously been added. The mixing shaft revolves at a velocity of 70 to 80 revolutions per minute. After 30 seconds a bottom emptying valve is opened, and the centrifugal force

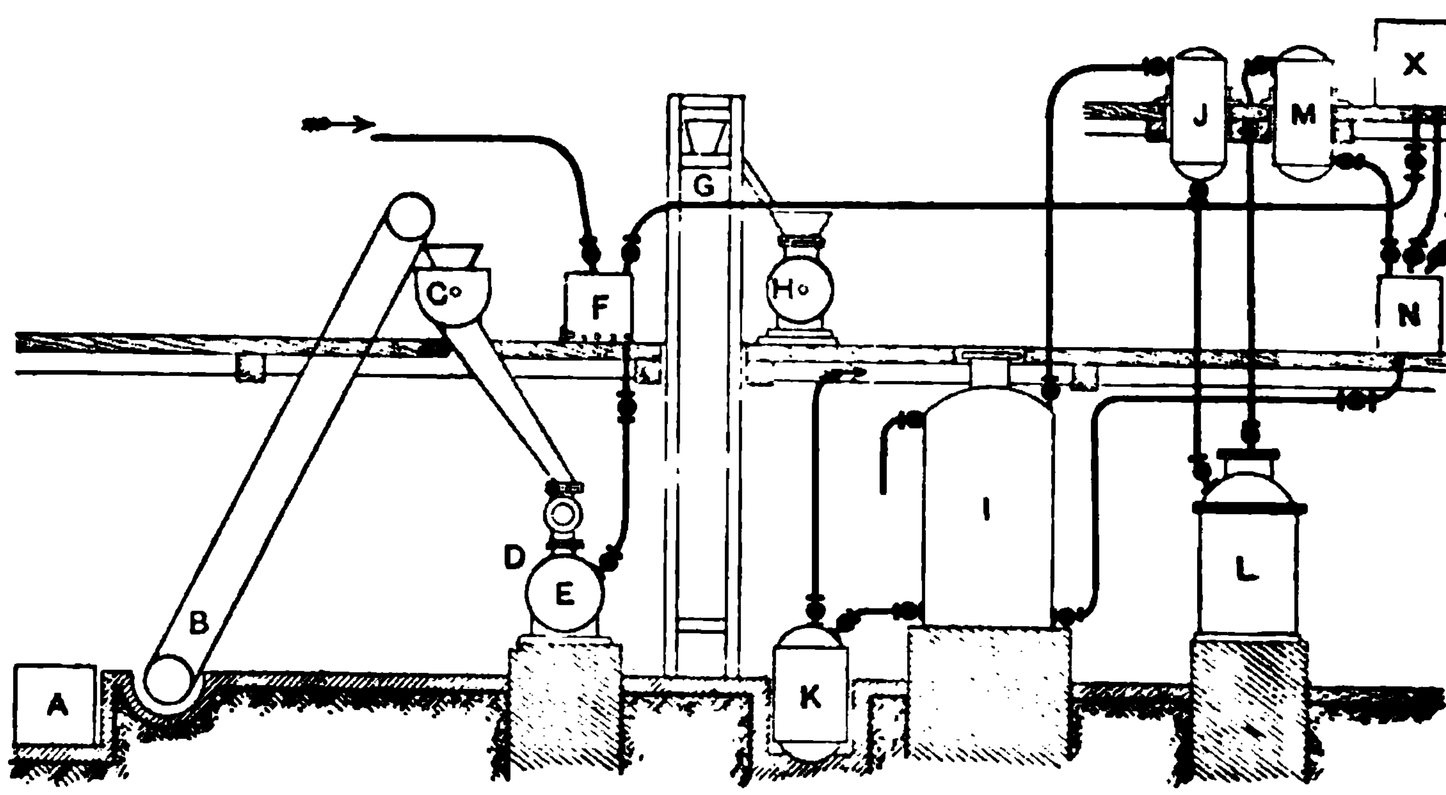

FIG. 217.—Schema of the MANOURY Process.

drives out the molassate from the apparatus. It consists of a sand-like granulated product, which contains considerable lime in excess. A lift, *G*, carries it up to a certain elevation, from which it is emptied into a sifter, *H*, where the lime in excess is separated. The molassate of lime is placed in elutors of much the same design as those mentioned in the SCHEIBLER process. At the upper portion of these is a large valve, for the escape of the alcohol liberated when the product is heated by the bottom steam coil. This alcohol finds its way into *J*. A series of cocks permits the introduction of the several grades of alcohol into this receptacle.

The MANOURY plant under consideration consists of four elutors. Into the first, alcohol at 42° is introduced from the reservoir, *N*. to a height of one meter above the double bottom. If the alcohol is not of sufficient strength, very concentrated alcohol from *Z* may be added. When it is within 30 cm. of the upper border, it is en-

tirely filled with alcohol, first by leaving the elutor open, then by tightly closing it, and leaving open the air-escape vent. The elutor remains under the pressure of the reservoir, *N*, for three hours, during which time the non-sugar is dissolved.

It is to be noticed that, owing to the addition of sodic carbonate to the molasses, all the calcic organic salts which are insoluble in alcohol are changed into soluble sodic salts. These are removed by the alcohol, and the remaining calcium carbonate may be readily removed from the epurated saccharate. The alcohol from elutor No. 1 is run into No. 2. When this liquid reaches within one meter of the top, an analysis is made by distillation (for the reason that the salts dissolved would influence the reading of the spindle) to determine the quantity of alcohol in this liquid. Concentrated alcohol is added so as to maintain the conditions at 42° in volume. The filling continues as for No. 1, but, three hours after introducing alcohol from No. 1, the mass is agitated. The same operation continues with No. 3, and at that moment the elutor No. 1 is ready to be emptied. The alcohol is drawn into a montejus, *K*, that forces it into a reservoir which feeds the rectifier, *L*.

When all the alcohol of elutor No. 1 has been drawn off, the communication is made between it and the condenser, *J*, and steam is introduced into the bottom steam coil of the receptacle. The saccharate becomes fluid and half of it is sent to the fourth elutor of the battery, so as to prevent excessive frothing, which is always to be feared when the elutor is too full. On this account a steam froth arrestor is generally placed in the apparatus. A distillation is then made in the two elutors, and this ceases when the condensed liquor indicates zero. The elutor is then emptied and washed, and the saccharate obtained is sent to the defecators. During this time, alcohol strained from No. 1 is sent to No. 2, and to No. 3 that from elutor No. 2. As soon as No. 3 has rested for three hours, the alcohol with the non-sugar in solution is sent to *L*, where it is distilled. This drawing-off is done by means of the strained alcohol introduced into No. 2; but when this gives out, the washing continues with pure alcohol from *N*. When it is thought that sufficient impure alcohol has been drawn off, No. 1 is filled to a height of one meter above the double bottom with alcohol, molassate being simultaneously introduced. During this interval, No. 2 is being emptied, and this manœuvre continues indefinitely.

Practical experience shows that for three elutors and for mo-

lasses of an average composition, 2½ liters of alcohol at 42° are needed for one kilo of molasses. The distillation is conducted so as to obtain alcohol of two different concentrations, one concentrated alcohol above 50° and the other below 50°. As the mass becomes viscous towards the end, the distillation is facilitated by steam injection, and, if necessary, water is added so that the liquid is at 41° to 42°. The water reservoir is shown in the illustration by *X*. The purity of the saccharate obtained varies from 89.3 to 93.4. As regards the residuary product from distillation, the wash, according to VIVIEN,[1] if brought to a basis of 15° Bé., contains 6.77 per cent of sugar and 14.25 per cent of ash, of which 3.85 per cent is potash.

Sostmann, Drevermann, and Gundermann process.—By this method the molasses first undergoes a preliminary epuration. To 5000 kilos of molasses a water solution is added, consisting of 100 kilos of calcic chlorid and 50 hl. of alcohol at 80°. The liquor, which should be strongly alkaline, becomes cloudy, owing to the transformation of the organic potassic and sodic salts into the corresponding lime salts. Carbonic acid is introduced, and is followed by a precipitation of the lime organates. It is very important not to exceed the point at which the liquor would become neutral. The solution is filtered, and lime is then placed in a closed receptacle with alcohol at 35 per cent, so as to form an alcoholic milk of lime. This operation is accompanied by a very violent reaction which is actually dangerous.

To the alcoholic milk of lime, purified molasses is added in the proportion of 100 parts of molasses for 33 parts of lime. During a period of four hours the mixture is forced to circulate between a cooler and a mixer, and *vice versa*. The lime saccharate will almost entirely precipitate under these conditions, and it is run through two filter-presses, in which the saccharate cake is first washed with alcohol at 15°, and then with alcohol at 35°. The remaining alcohol is removed by means of compressed air, and the saccharate is then ready to be used during defecation. The mother liquors are distilled and the alcohol is regenerated. The purity of the saccharate varies from 89 to 91.

One of the principal advantages claimed for this purpose is that very little lime is used, and it is possible with this sugarate to return more sugar to the juice for a given quantity of lime used

[1] Procedé MANOURY, 58, 1879.

than by other modes having the same object in view. Most of the elution processes have been abandoned, owing to the complication connected with the successive handlings, and to the expense due to loss of alcohol during each operation. However, the idea is a good one, and perhaps, with a few changes, these methods might again come into vogue. Cheap alcohol would give the entire issue another aspect. There are numerous elution patents, but the processes that have attracted the most attention are those mentioned in the foregoing.

CHAPTER III.

SUBSTITUTION AND SEPARATION.

General considerations.—During PELIGOT's investigations, in 1838, he discovered that aqueous solutions of mono-saccharates of lime, when hot, formed an insoluble trisaccharate of lime holding one-third as much sugar as the mono-saccharate. Many other investigations were made, the most important of which appear to be those of SEBOR, whose process gave practical results and was introduced into several sugar factories. For many years it was kept secret, and was, therefore, regarded with some suspicion and was not generally used.

Substitution.—POZAREVSKY's[1] experiments were also based upon PELIGOT's investigations. The practical experiments of STEFFEN led to the process of substitution of BUONACCOSI, STEFFEN, and DRUCKER. It is based upon the formation of mono-saccharate and a bi-saccharate of lime, and the transformation, when hot, into a tri-saccharate of lime. The sugar and the lime dissolved are separated by filtration from the tri-saccharate. To the solution more molasses is added, so as to make a cold precipitate of the mono- and bi-saccharate of lime, followed by another hot decomposition into tri-saccharate of lime and a solution of lime and sugar. The latter is again treated in the same manner.

The operations are repeated 20 to 25 times, or until the quantity of non-sugar accumulated in the water is such that all future manipulations would be useless. The tri-saccharate undergoes several washings, and is finally transformed into a milk saccharate of lime, which is sent to the defecators. This process was much in vogue for many years. Some experts[2] claim that it reduces the sugar losses to 2.65 per cent of the molasses. The saccharate obtained had a purity of 90. The quantity of lime used is equal to the quantity of sugar being handled. Owing to certain difficulties

[1] Z., 26, 208, 1876. [2] BEAUDET, 2, 58, 1894.

of manipulation this method has been abandoned, and the STEFFEN separation process has taken its place.

Separation.—This method consists in the formation of an insoluble tri-calcic saccharate improperly called tri-saccharate of lime and its separation by filtration, the mother liquor containing nearly all the impurities of molasses. CLAASSEN says that "separation" is the most advantageous of all the processes of desugarization of molasses, which operation may be conducted simultaneously with the manufacture of sugar from the beet, provided sufficient cold water at 10° to 12° C. is available. The method is very simple,

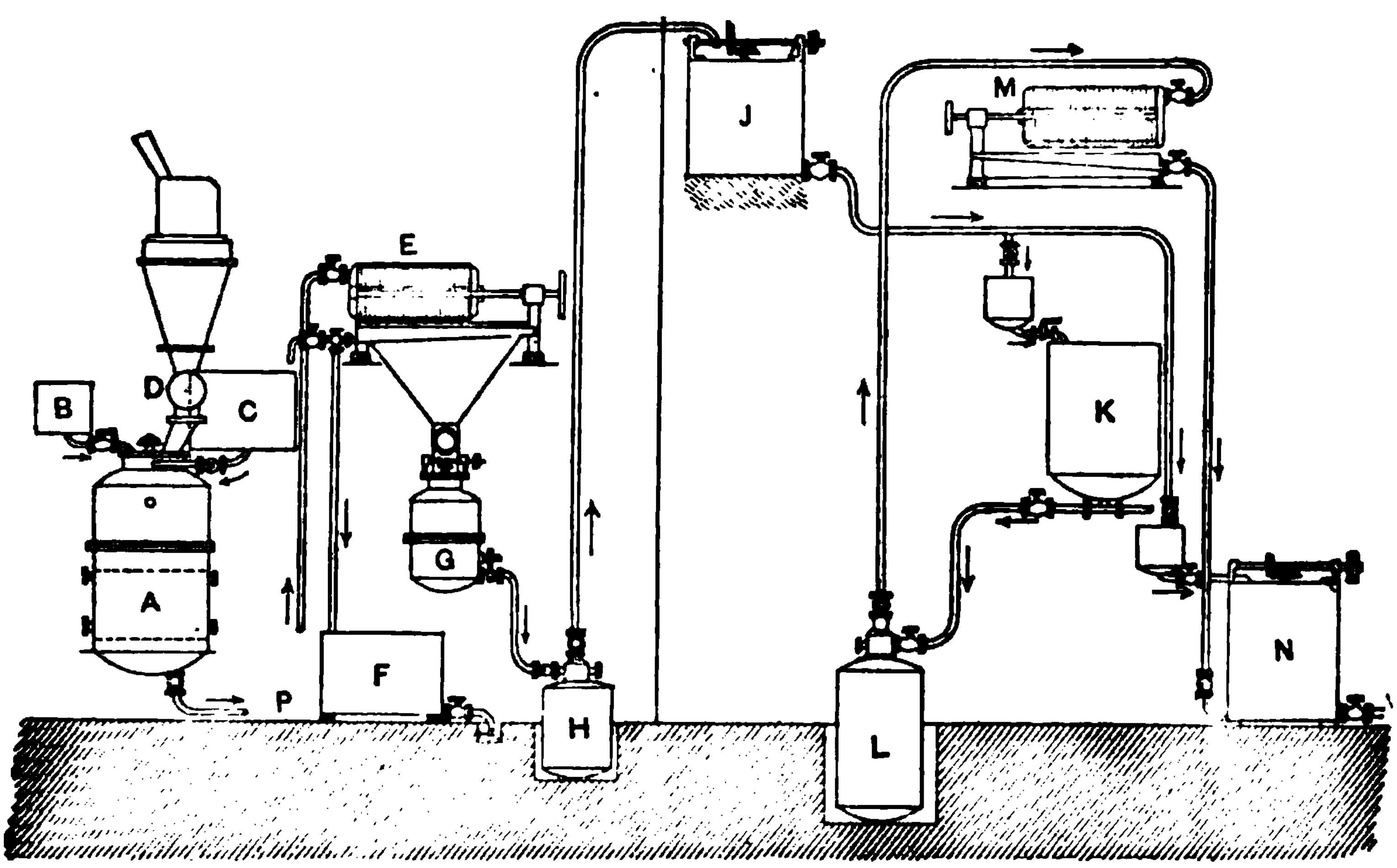

FIG. 218.—STEFFEN'S Separation Process.

and results in a comparatively small sugar loss. The STEFFEN process consists in the following manipulations: The molasses from the receptacle, *B* (Fig. 218), is diluted in the refrigerating mixer, *A*, with the sweet water of the saccharate presses. This is collected in *C*, a weighed quantity of lime is added, and, when the precipitation is thought to be complete, the liquid is forced by means of pumps into the filter presses, *E*. The mother liquor of the solution is thrown away, and the saccharate remains on the frames of the filter press. The saccharate cake is washed with the requisite quantity of water, the volume depending upon the purity desired for the saccharate. The exit flow of this water from the presses is collected in the receptacle, *C*; it is used as just described for diluting the molasses, and the sugar it contains will thus be utilized.

In some cases there seems to be an advantage in drying the saccharate cakes by means of compressed air, which is forced into the presses through the same passages as the water used for washing. The presses are then emptied into a spiral carrier, which transfers the saccharate into the mixer, *G*, where it is diluted. A monte-jus, *H*, forces it into another receptacle, *J*, having suitable agitators, and then it is drawn off little by little into a measuring device, from which it flows into the carbonatator, *K*. The carbonatated juice is forced by the monte-juice, *L*, into the filter presses, *M*, and from there it runs into another mixer, *N*. The lime for the second carbonatation is added during the mixing in the form of milk saccharate, and comes from a measurer connected with the apparatus.

The Steffen process consists of the following operations: (1) The production of powdered quicklime; (2) formation of a saccharate at a comparatively low temperature; (3) separation of the tri-saccharate of lime and its washing in the filter presses.

Production of the powdered lime.—One of the most essential details for the successful execution of this process is, that the lime used shall be exceptionally pure. The limestone should contain a minimum percentage of magnesia, silicic acid, and alumina; in other words, a minimum of all those substances that favor the fusion of lime. It is to be noticed that the lime acts in solid form, and not in the form of a solution. In order to obtain a perfect contact in a reaction of this kind, it is necessary that all the molecules of lime should be as far apart as possible. Lime in dust-like or flour-like conditions will much more readily enter into the combination than another variety in coarser granules, or in which the molecules have become agglomerated through fusion. If the lime is not porous, a greater amount of it must be consumed to produce a given effect, and, furthermore, unfavorable conditions of working result.

It is also necessary to remove from the lime everything that may possibly be considered as impurities, since these give rise to misleading indications in the measuring appliances. Fresh lime, if possible, direct from the kiln, should be used; for experience shows that, when it has stood for some time without necessarily having absorbed carbonic acid that would have saturated a portion of the product, the lime will not so readily combine during this special phase of working. The lime should always be cold, as, when hot, it possesses the property of easily forming an agglomerated

mass, and the lumps are not easily handled in the distributing hoppers. The sifting of hot lime is always more difficult than cold. If thrown into cold water, it will at once be slaked with a corresponding elevation of temperature, whereas, in the operations under consideration, the oxid of lime only can combine with sugar.

Numerous appliances are used for crushing the lime. When the process was first introduced, simple grindstones, such as are used in flouring mills, answered the purpose. The lime was broken into lumps, and was then placed on two grinders one over the other, the lower one being fixed and the upper having a rotary motion around its vertical axis. The powdered lime was sent through a sifter, in which there were two classifications of the product. The exterior and smaller sieve has a mesh of 200 per square centimeter. The sifted lime is distributed into the precipitation appliances by means of a spiral and a suitable hopper, while the portions separated are again sent through the crusher

Now it is customary to use crushers of very much the same model as those employed for cement. The lime is first introduced on the side of a solid cast-iron drum, which is closed by suitable sieves, these sieves covering an arrangement of slightly inclined cast-iron blades. In the interior of this mill are placed 20 to 50 cast-iron balls, having each a weight of 10 kilos. The lime is continuously forced through the sieves, owing to the continued crushing. The mesh of the sieve varies from 3 to 5 mm. The 3 mm. dimension is rarely used, as the mill would demand too much power; 4 mm. may be said to be an average. Upon leaving this mill, the lime enters a second mill or crusher, consisting of a horizontal cylinder, 3.5 m. in length and 1.20 m. in diameter, and revolving at a velocity of 30 revolutions per minute. It has an inner lining of hard fire-bricks. Through a special manhole, 1200 to 1500 small silex stones are introduced into the interior, each having a diameter of 5 cm. At the other end, from the entrance on the outer periphery, is a grating, which allows the powdered lime to escape, but holds back the stones. As these sometimes break, it is found desirable to cover the grating with a coarse-wire cloth.

This crushing is most satisfactory, resulting in an impalpable powder, the degree of fineness depending upon the hardness of the lime, and also upon the number of friction rollers in the interior of the cylinder. Generally, these fill up half of the receptacle. The

powdered lime is carried by some mechanical means to a rather fine rotating sifter, intended to retain the undesirable portions of the lime. The resulting powdered lime collects in a receiver, from which it is taken to the precipitation receptacle or cooling mixers, being first, however, carefully measured.

Of late the RAYMOND lime crushers of a quite new design have met with considerable success in the United States. They consist of a vertical sheet-iron cylinder, provided at its lower portion with a very strong cast-iron ring, on the inside of which run three rollers of considerable weight. The lime introduction is effected by a hopper on the side, and regulated by means of a ratchet wheel. A powerful ventilator aspirates the lime into the upper portion of the cylinder, enlarged so as to form a funnel. By means of a regulating device with tangential wings, a whirl is produced into the funnel, and only the very fine dust is carried forward with the aspirated air, while the coarser particles fall down into the crusher proper and are ground finer. The aspirated air carrying forward the lime dust enters a cyclone very much like those used in flour mills, and there abandons the entrained lime dust. The fineness of the powder obtained can be regulated at will by means of the tangential wings previously mentioned, and the results are so perfect as to do away with any sieve, all of it passing through a sieve of 200 meshes per square centimeter.

Precipitators. — These are cylindrical appliances (Fig. 219) with a tubular surface very much like those used in a vertical evaporator. In this case it is cold water that circulates between the tubes, *r*. A vertical shaft, *c*, passes through the apparatus from top to bottom. It has agitating arms, *d*, and a small screw, *e*, and makes 200 revolutions per minute. The molasses is introduced into this apparatus at *f*. The lime is introduced at *g*. Water enters the tubular chamber by *a*, and leaves at *b*. A certain number of manholes, *n*, permit the different parts to be examined when necessary. To keep down the froth, there is a perforated upper coil, through which cold water circulates and showers down upon the froth, thus

FIG. 219.—STEFFEN'S Cooler.

reducing it. Exterior to this apparatus are a sampling cock, peep glasses, and sometimes a water level and a thermometer.

The practical working by this process consists in first weighing or measuring a quantity of molasses, corresponding to the capacity of the apparatus. The residuary water from the filter presses is added, so as to obtain a density of 12° Brix. and from 6 to 7 per cent of sugar. The agitators are started, and, when the liquid is cooled to a temperature about equal to that of the water used for cooling, lime is introduced by a special measurer. One quarter of a revolution allows a given weight of lime to escape. It is important to note that an energetic mixing is absolutely necessary, in order to increase the heat transmission through the cooling surfaces, and to rapidly and uniformly distribute the powdered lime.

Upon general principles, it may be said that the more rapidly the operation is accomplished, and the finer the powdered lime, the more satisfactory will be the final results, as the rapidity of the combination of sugar and lime into an insoluble saccharate is thus correspondingly increased. On the other hand, the lime that forms lumps and combines with water is hydrated, and is thus slaked and inactive. The greater the quantity of lime thus rendered inactive, the greater will be the heat evolved, and this demands ultimately, besides a greater weight of lime, a longer cooling and mixing of the liquid. In order to prevent the lime powder from collecting into lumps in the liquid being mixed, it is proposed not to add a mass of the powder at once, but to spray it upon the surface of the liquid by means of a sieve placed on the upper part of the mixer, or to force it into the apparatus by means of a ventilator.

The Härje apparatus also is of some interest. It consists of a cylinder with a large tubular surface, from the upper part of which a trough 2 meters in length extends. The other extremity communicates with the bottom of the cylinder by means of a pipe, on which there is a centrifugal pump revolving at a considerable velocity. In the trough there is an agitating spiral, which keeps the liquid continuously in motion. Upon the surface of the liquid in this trough, lime is slowly projected by means of a rotating brush, the rapidity of the addition of the lime depending upon the progress of the precipitation. Under these conditions the desired object is attained. This apparatus has a dial upon the lime distributor, permitting a more careful measuring than is possible with the appliance previously mentioned.

Bethany[1] obtains a uniform distribution of lime in the solution of diluted molasses by using a sieve distributor. The refrigerating apparatus is wider on top, so as to give a considerable surface contact to the liquid and lime. A spiral forces the liquid upwards. The combination with lime is said to be completely effected in the centre of the appliance. Kempe and Nathhorst[2] endeavored to attain the same results by using a blower to project the lime on the surface of the liquid.

Practical working of the process.—The molasses solution having been obtained, and subsequently cooled to 12° or 15° C., the lime is gradually introduced, and this is necessarily followed by a rise of temperature, which in the now obsolete Steffen appliances frequently reached 8° or 10° C. The lime addition continues, and when the quantity determined upon in advance to obtain the desired precipitation has been placed in the mixer, the agitation continues until the spindle in the filtered liquid shows 6.0 or 6.5° Brix. By recent methods the alkalinity of the filtrate is determined for ascertaining if the precipitation is complete. It is considered to have reached its limit when the alkalinity is 0.8 per cent oxid of calcium. The quantity of lime used varies from 90 to 175 per cent of the quantity of sugar contained in the molasses being handled. The degree of fineness is almost only responsible for the consumption of lime. The excess of lime may, when slaked, be the cause of an explosion in the filter presses. The cloudy liquid is sent to the filter presses, which are covered with hemp cloths. While this fabric is the most desirable that could be used, it is soon eaten away, especially when the saccharate contains an excess of lime. These cloths should be washed in cold water.

The filtration of the saccharate offers no special points of in terest. It is done under a pressure of 1.8 atmospheres, and no complications other than those mentioned occur. When all the mother liquor has run off, representing a volume of 800 to 1000 per cent of the molasses being worked, the entrance cock is closed, and water is forced into the presses in order to wash the saccharate cakes. All the remaining non-sugars are thus removed. During this washing a certain quantity of saccharate is also dissolved, as it is partly soluble in pure water, and, that it may not be lost. these waters are used for diluting the molasses in the mixers, Other modes have been proposed to prevent this loss; for example, it has been suggested[3] that the washing be done with a saturated

[1] D. R. P., 90,159, 1896. [2] D. R. P., 101,696, 1897. [3] B. Z., 9, 80, 1884.

lime solution. HÄRJE suggested that a liquid be used that would hold in suspension a lime saccharate of a lower percentage of saccharate than that from which was grained the cake being washed in the press. It is said that under these circumstances only the mother liquor is carried off and the saccharate remains intact. The sweet water is used to dilute the molasses in the mixer as usual. The outcome of this idea was that two molasses solutions were simultaneously prepared, one of them being more dilute than the other.

STEFFEN[1] took this idea as a departure for another process, in which a series of three cooling mixers of slightly different construction are used. He recommended that the process should be applied to the after-products from "firsts," but it may be applied to the case under consideration as well. About two-thirds of a given quantity of the after-products is diluted at first with cold water, and later with what the inventor terms "water from white washings" at about 13° Brix., the remaining one-third being diluted until it has a density corresponding to 3° or 4° Brix. The solution at 13° Brix. is sent to two of the appliances, known as black precipitators, and the solution at 3° to 4° Brix. into another apparatus, called white precipitator. The centrifugal pumps are then set in motion. The reaction in the black precipitators is completed in 20 to 30 minutes, while, in the white precipitators, only 15 minutes are required, these periods depending upon the temperature of the solutions, which should never be higher than 16° to 17° C., as there would otherwise be considerable frothing. Further, a portion of the lime would at once become hydrated and escape the reaction.

The combinations are considered finished when the alkalinity is found to be 0.7 or 0.9 grams of quicklime per cubic centimeter of juice. The black solution shows this alkalinity at the beginning of the reaction; it then increases to 2.8 grams, and in eight minutes it falls to 0.7 to 0.9 grams. The black solutions are first forced through the filter presses, and then the white ones follow in the same filters. The mother liquor of the white washings, being more diluted than the black, wash the saccharate of the latter, which is followed by a second washing with water. This water is called white washing, and is collected and used for diluting the syrup for the black solution. With 100 parts of an after-product having a

[1] B. Z., 24, 386, 1899–1900.

purity of 63 to 66, 300 parts of saccharate holding 35 per cent of dry matter is obtained, which contains 55 per cent of sugar and 45 per cent of quicklime. The saccharate should be filtered at once, otherwise it will redissolve.

For the practical working of this process it is essential that the filter-press frames be not entirely filled with the saccharate; otherwise the product from the white washings will not have a place for their deposit, and this solution can no longer pass through the saccharate cakes. In a Swedish factory at Karpalund, where the Härje process is applied, frames covered with a varnished oilcloth are put between the regular frames of the filter press in which the saccharate accumulates. The filtration under these conditions is only on one side; but this is not a disadvantage, as the liquid readily filters, and cakes are obtained of 5 cm. thickness. After the mother liquor has run off, the washing begins, and, as the varnished oilcloth is more or less flexible, it leaves sufficient space for the saccharate to be deposited. After the washing, compressed air is introduced on the other side of these cloths, which drives out from the cakes the water absorbed during the washing.

With all these different modes of working, it is possible, according to the degree of washing to which the saccharate has been submitted, to obtain a product the purity of which reaches 90. By extending the period of washing, a purity of 94 and even 95 may be attained. It is to be noted that the losses are greater than when the cakes are not so thoroughly exhausted of their non-sugar. However, it is claimed that, whatever losses there may be, they are less than by the other processes mentioned in the foregoing; but, argue as one may, they are much greater than is generally supposed. The waters thrown away, under the best conditions of working, rarely contain more than 0.5 per cent of sugar; but, if one takes into consideration that there is from 800 to 1000 per cent of mother liquor allowed to run to waste, the loss in reality represents $\left(\frac{0.5\times 1000}{100}\right)$ 5 per cent of sugar calculated upon the molasses, or 10 per cent of the total sugar handled. When the working is conducted under faulty conditions, due either to the lime, excessive temperature, or to a perceptible amount of glucose in the molasses, etc., these losses may be readily doubled. Such being the case, it is evident that the process demands great care and should be conducted upon truly scientific principles.

Up to the present time, these residuary waters have found no

profitable utilization, although certain experiments have been made in Russia [1] with the idea of using them upon soils as a fertilizer. From all accounts, these experiments were successful. Investigations [2] were made to determine what possible advantage there would be in applying the STEFFEN precipitation process to diffusion juices after defecation with 0.5 per cent of lime. Under these conditions it is claimed that purity of 95 to 96 was attained. Losses during washing of the saccharate reached 0.4 per cent. In order not to have an excessive loss of sugar, it was proposed to push the diffusion to an extreme limit. The quantity of lime needed by this method varies from 7 to 8 per cent, and this quantity did not appear excessive to those who were interested in the success of the idea.

Other experiments were made to desugarize the after-products of "firsts." According to EHRHARD,[3] this would involve an enormous expenditure of lime, which in weight would not be less than 6 per cent of the beets sliced, and would add to the cost of handling. If to this fact one adds the cost of the plant and the sinking fund, it cou d be readily demonstrated that there would be little if any, financial gain by the use of the process. He recommends that the after-products from "seconds' be handled according to the new mode. There is then less lime needed; the process is, consequently, more economical, and the carbonatation tanks are able to handle the amount of lime involved.

Use of saccharate.—The moist saccharate, as it leaves the filter-press, contains from 12 to 15 per cent of sugar and from 15 to 20 per cent of calcium oxid. In some exceptional cases a saccharate containing more sugar than lime is obtained; in no case does it agree with theory. The so-called saccharate is a mixture of saccharate and uncombined lime. The nature of the non-sugar combined with the saccharate has not as yet been determined. Apparently, the saccharate is very different from that which would have been obtained by boiling lime in saccharine solutions. When the saccharate is taken from the filter presses it is worked up into a milk of saccharate of lime. Numerous appliances have been used for this purpose, and experience shows that it is desirable that their capacity be reasonably large, so that the product may be uniform in composition. When mixing or kneading this saccharate it is

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[1] Bl., 6, 343, 1899. [2] D. Z. I., 24, 1395, 1899.
[3] C., 11, 707, 1903.

first changed into a thick paste; then, to render it more fluid, a small quantity of juice is added, and for this purpose it is better to use carbonatated juice. When the mixing is done with fluid juices, the saccharate from the presses changes into hydrated lime and mono-saccharate. This mixture has an energetic action during the defecation of diffusion juices.

There need be no apprehension, even at 70° C., that tri-saccharate only partly soluble will be formed, which product is but slowly decomposed by carbonic acid, and may increase the sugar percentage of the scums. This tri-saccharate may be formed through the influence of high temperatures, and is the outcome of having added the saccharate in a thick, cold, pasty condition to hot diffusion juices. Beet-sugar factories that handle only their own molasses in their separation plant add, by means of saccharate, about 2 to 2½ per cent of lime to the juices; in other words, just about what is actually needed. On the other hand, when advantages appear to be obtained by the desugarization of purchased molasses, an excess of lime enters in this way the defecation. In such cases CLAASSEN recommends to mix the excess of saccharate with fresh juice, and to eliminate, by filtering in press, the hydrated lime which is precipitated. Under these conditions it is readily separated. After washisg, this hydrated lime may be added to diluted molasses, in which it will dissolve as a mono-saccharate, and this will effect an economy in quicklime.

Upon general principles, it may be said that it i a mistake, from a financial point of view, to attempt to handle more molasses than the beet-sugar factory furnishes, as even in this case difficulties arise in the subsequent crystallization, and they would be still greater if the operations had to be conducted without the addition of fresh juices. When conducted under rational conditions, the cost of working by this process is very slight. The juices that can be directly obtained from the saccharate have a purity of 90 to 94; that is to say, about the same as those obtained directly from the beet. They offer, however, greater difficulty in crystallization, and this explains why the yields of first-grade sugars from a masse-cuite obtained with pure beet-juices is generally greater than when the saccharate has been added. These saccharates generally contain a small percentage of raffinose, which seems to be too frequently overlooked, yet its quantity constantly accumulates as the campaign progresses.

These difficulties of crystallization apparently are due also to

the constituents of the non-sugar which obstructs crystallization. Certain calcic salts are not eliminated through separation, but remain with the saccharate, and are added to the beet-juices. These, with the raffinose, are precipitated by the lime at the same time as the sugar. They accumulate in the molasses in factories working by the separation process. When this molasses is worked from year to year, these quantities will constantly increase, and theref re it is essential that the residuary molasses should be entirely shut out after a reasonable interval of time. By this simple precautionary measure, the decreased yields of "firsts," and the inferior quality of the sugar obtained, from a refiner's standpoint, will be averted. However, there is often a fraction of difference in the selling price upon the market of these separation sugars as compared with those from a standard beet-sugar factory.

CHAPTER IV.

STRONTIA AND BARYTA PROCESSES FOR DESUGARIZATION OF MOLASSES.

General considerations.—PELIGOT[1] was the first one to direct attention to the insoluble combinations of baryta and sugar. According to SCHEIBLER[2] it was in 1850 that ANGUS SMITH proposed that strontia and baryta be used for the desugarization of molasses; but it is to be noted that DUBRUNFAUT and LEPLAY had taken out their patents relating to the same subject in 1849. Twenty years later FLEICHER[3] took up a series of investigations to determine the action of strontia upon saccharine juices, and the outcome of these experiments was the introduction of a process that was thoroughly tried in two German beet-sugar factories.

SCHEIBLER then invented two new processes which were very different; one of these was based on the formation of a bi-basic saccharate of strontia, and the other on a mono-saccharate of strontia. Up to that time the chemical in question, owing to its cost, had been of no use in the beet-sugar industry, as very few deposits of strontia were then known outside of certain sections, of Germany. The strontianite,[4] which is a carbonate of strontia, is a mineral found in some abundance in Westphalia, at Braunsdorf, Saxony, near Klausthal, Salzburg, and at Strontian, Scotland. The SCHEIBLER bi-basic saccharate of strontia method is about as follows:

To diluted molasses, strontia is added in excess, so that, by heating, the compound in question is formed. Nearly all the sugar is precipitated by boiling; and the mixture is emptied into receptacles with double bottoms acting as filters, the remaining mother liquor being drawn off, and the precipitate washed with liquors containing 10 per cent of strontia. These operations are all done hot. The

[1] S. I., **20**, 275, 1822.
[2] Bull. Asso., **2**, 23, 1884.
[3] STOHMANN, Handbuch, 623, 1899.
[4] D. Z. I., **6**, 1124, 1881.

bi-saccharate of strontia is then cooled, and decomposes nto a hydrate of strontia, which crystallizes in liberating the sugar. This cooling is effected by the circulation of cold 2 per cent strontia solutions through filtering receptacles arranged in battery containing the saccharate. In this way a 10 per cent sugar solution, containing also some strontia, is obtained, while, in the washing apparatus, crystallized strontia remains. This is cured in a centr. ugal, and is subsequently returned to the general work. The saccharine solution is subm tted to a carbonatation, and the strontia carbonate is regenerated.

In the mono-saccharate of strontia process the saccharate is precipitated cold by the addition of a strontia solution to the molasses, and for this purpose one part strontia for one part sugar is used. Then follows a filtration and a cold-water washing. With the strontia-saccharate cakes a milk is obtained, which is twice carbonatated. The sugar is extracted from the mother liquor by the addition of strontia, and a bi-basic saccharate of strontia is then formed. This is used in the process at the moment of the format on of the mono-basic saccharate of strontia. From the mother liquor of the bi-basic saccharate, strontia is extracted by crystallization and carbonatation. Of these two methods, the bi-basic saccharate has been the one generally adopted.

Scheibler strontia process (Fig. 220).—In the vertical cylindrical apparatus, *A*, heated by steam, there are received by the hopper, *D*, 750 kilos of crystallized strontia from the regenera ion receptacle, and through *C* a quantity of mother liquor of the crystallization of strontia. There follows a mixing and heating so as to dissolve the strontia. Then 300 kilos of molasses heated to from 65° to 70° C. are introduced from *B*. The heating is cont nued until it reaches 100° C., and during this interval the mass is constantly agitated. After 30 minutes the bi-basic saccharate of strontia is in a pasty condition in a non-sugar mother liquor with dissolved strontia. A double bottom trough with an agitator is heated by steam, and distributes the saccharate into three strainers, *F*, *F*, *F*. These receptacles are suspended, and their positions on their axes may be slightly changed, so that the emptying faucet comes over the gutter, *H* or *I*, as the requirements demand. Upon the fi tering cloths of the strainer, *F*, there is placed a layer of 100 mm. of saccharate, corresponding to 350 litres, and above the saccharate there is a free space. A vacuum is created under the filtering cloth. The mother liquor passes through the false bottom, and is carried

by the gutter, *I*, into the reservoir, *J*. By *R'''* and *G*, a 15 per cent solution is brought upon the saccharate, so as to wash it as completely as possible. The passage of these waters is facilitated by

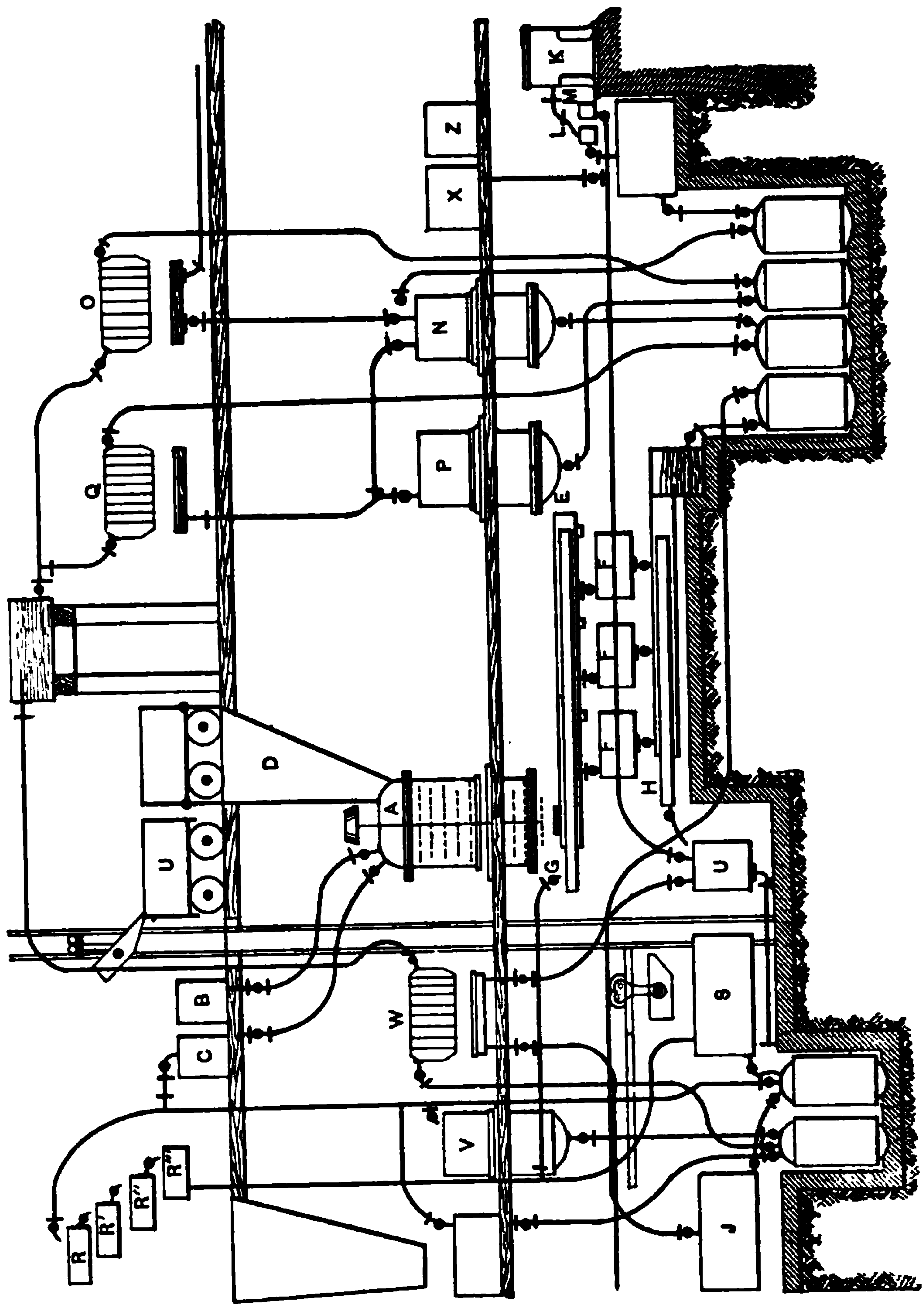

FIG. 220.—Schema of SCHEIBLER Strontia Process.

the vacuum, and the gutter, *H*, carries them to the reservoir, *U*, from which they are subsequently taken to extract the strontia.

The saccharate is shovelled into small crystallizators of 25 kilos

capacity of saccharate, and kept for from 24 to 36 hours at a temperature of 5° to 6° C. The bi-basic saccharate then decomposes into crystallized strontia and a sugar solution, still holding some of this compound. These crystals are centrifugated in K, and subsequently cured with a 1 per cent cold strontia solution. The juice, as well as the first waters of washing, are brought by L to the first carbonatation, N, while the last waters from washing, which no longer contain sugar, are sent by M into the reservoir, U. The carbonatation, by means of the carbonic-acid gas of the strontia kilns, is continued until the solution reaches an alkalinity of 0.05 or 0.03 per cent of oxid of strontia, when it is sent to the filter-presses, Q, and then into the second carbonatation tank, P.

The carbonatation continues until the liquor is neutral, when it is then filtered through Q. The juice is mixed with the raw-beet juices of the factory, and the scums are submitted to a special treatment, so as to regenerate the strontia. The mother liquors, separated at F and collected in J, will, when decanted, abandon nearly one-half of the strontia hydrate they retained in solution. This strontia is sent to the precipitator, A. After an interval of 36 hours these waters contain only 3 per cent of strontia oxid. There follows a carbonatation of these waters in V, so as to extract what remains of the strontia. The carbonate of strontia is separated in the filter press, W; the resulting cakes are washed, and the product is combined with the cakes of the presses, O and Q. In the vats, R, R', R'', and R''', a solution of strontia is prepared by means of burned strontianite; it is allowed to crystallize in S, and the excess of mother liquor which is not used in A is forced into the carbonatation tanks.

The same conditions prevail as regards the residuary water from washing the saccharate in F, and the crystals of strontia in the centrifugal, K, that were collected in the reservoir, U. The crystallized strontia of the mother liquor of the saccharate, which was sent by I to J, and the crystals from K, are worked up in the precipitator, A. It remains to regenerate the strontia carbonate which has not burned from the vats, R, R', R'', and R''', and the different scums. The cakes are combined with the crushed strontianite necessary to compensate for the losses, and are made up into bricks. When the sugar campaign of the factory commences, the bricks are made of pure strontianite, moistened with a 1 per cent solution of oxid of strontium. An apparatus presses the product into the desired shape, and it is then dried above the regenerating

furnace, and subsequently put into the strontia furnace. This consists of 12 rooms, upon the floors of which are arranged briquettes heated with gas from a gasogene, the circulation being through well-arranged perforations. A very high temperature of about 1300° C. is necessary to decompose the carbonate. The carbonic-acid gas is utilized during carbonatation, but it contains only 7 to 12 per cent of pure carbonic acid. Fifteen hours are necessary for the complete transformation of the briquettes. They are dissolved in the vat, *R*, in which there is a steam coil, and after three decantations in the vats, *R'*, *R''*, and *R'''*, the nearly pure solution is sent into the reservoir, *S*, where the strontia crystallizes and is then used in *A*. The mother liquor of this receptacle is used in the manufacture of the briquettes or is carbonatated in *V*.

By this process [1] there is a loss of 2.5 to 5 kilos of sugar per 100 kilos of molasses used in the work, and 3.7 per cent of strontia, or one part of strontia for 1 part sugar. Some modifications have been made in this process, but they relate to details only.

SCHOSSTAG [2] washes the bi-strontic saccharate in the filter presses by first running through the residuary liquids used in the previous washings, separated from one another according to their purity. The most impure of the solutions is the first to circulate. The first water running off from the presses is sent to the carbonatators, and the others are separated to be again used. The washing of the cakes is completed by means of a pure solution of hydrated strontia. It is claimed that the first waters from washing will dissolve substances that the pure hydrate cannot carry off. In order to reduce the cost of labor, and to decrease the losses which are the necessary outcome of the manipulation of the bi-strontic saccharate, the strontia company [3] places in the saccharate straining cars a wire basket with a mesh of 4 mm. After the saccharate has been entirely separated and washed, all of it may be removed by the simple withdrawing of the basket, which is then taken to the cooling rooms.

KRÜGER [4] has suggested some changes in the strontia method of working molasses. Instead of cooling the strontia saccharate in wagons or baskets placed in a current of air, he dilutes the product with strontia washings, so that their consistency will allow them to be readily carried by pumps to a mixing refrigerator.

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[1] BEAUDET, Traité, 2, 90, 1894.
[2] D. R. P., 135,682, 1901.
[3] D. Z. I., 28, 853, 1903.
[4] D. Z. I., 24, 1137, 1899.

Most of the other modifications relate to the regeneration of the strontia. Without doubt, the difficulties for regeneration of the baryta and strontia have prevented these processes from becoming more generally introduced. It has been proposed to resort to electrodialysis for the direct regeneration. SCHEERMESSER[1] uses for this purpose an apparatus not unlike a filter-press, in which milk of saccharate and water, rendered an electric conductor by the addition of 0.01 to 0.1 per cent of hydrate of strontia, circulate alternately in the different compartments separated by parchment paper. The compartments holding the saccharate contain the anode. The strontia that separates from the sugar passes through the porous membrane, and is carried off by the water in the cathodic compartment. Very little sugar is said to be lost. The author does not know to what extent this idea, which seems simple, has been successful.

In order to transform strontia sulphate (celestine) into carbonate of strontia for the desugarization of molasses, GAERTNER[2] proposes to mix it with a solution of sodic phenate. It is claimed that the carbonic acid combines with the sodium, and that the sodic carbonate formed decomposes the strontia sulphate, the result being sulphate of soda and strontia carbonate. To the solution lime is added to regenerate the sodic phenate. The strontia carbonate is separated by filtration, and is transformed into oxid of strontia by the previously mentioned method.

The following processes were proposed not long since. One of them relates to the utilization of strontia sulphate for the preparation of strontia, and the other is a process of actual regeneration. WENK[10] contends that he obtained strontia carbonate by submitting a mixture of strontia sulphate, alkaline carbonates, and carbonic acid to a temperature of 175° C. under considerable pressure. If this method were practicable it would do much towards the general introduction of the strontia process for treating molasses. Sulphate of strontia is a far cheaper mineral than the carbonate (strontianite), and if it could be utilized indirectly for the fabrication of strontia in furnaces, as already mentioned, it would be of advantage, as the processes actually in use, to convert the sulphate into strontia, are too expensive.

According to SCHOSSTAG,[3] when a bi-strontic saccharate is decomposed cold, a strontia hydrate and sugar are not formed, but

[1] Z., 49, 409, 1899. [2] Z., 52, 754, 1902. [3] C., 9, 1125 b, 1901.

there will first be produced a saccharate containing 3 molecules of sugar and 2 molecules of strontia, and when cold this is decomposed into strontia, sugar, and a mono-saccharate of strontia. This mono-saccharate is insoluble, but it appears in a crystalline form, the crystals being so thin that they pass through the wire cloths of centrifugals at the same time as the saccharine solution, while the strontia remains in the drum of the centrifugal. By existing methods this saccharine solution is submitted to a carbonatation to separate the strontia in the form of scums, the dry matter of which contains 90 to 92 per cent of oxid of strontium and 8 to 10 per cent of impurities, such as sulphates and silicates of lime and strontium. A certain amount of free silica and metallic oxid renders the regenerated strontia very impure. SCHOSSTAG[1] adopts the following process: The saccharine solution, holding in suspension the mono-saccharate, is added to carbonatated juices in the proportion of 2 parts for one part of carbonatated juice. This is boiled, the mono-saccharate is dissolved, and the impurities are eliminated by filtration. The filtrate is carbonatated and the scum obtained contains 0.7 to 1.0 per cent of these impurities and 99 to 99.3 per cent of carbonate of strontium. The regenerate strontia is purer, and contains only 0.5 to 0.7 per cent of impurities.

The strontia processes are by no means in general favor. Numerous objections have been found to their general introduction in the beet-sugar factory. It is claimed that they help the formation of raffinose; but SCHOENE and TOLLENS,[2] by recent experiments, demonstrate that such is not the case. Mixtures of ten per cent sugar solutions, combined with 5 per cent strontia oxid at 125° to 128° C. in an autoclave during four hours, contain no raffinose. There are formed small quantities of lactic acid, and the liquor becomes slightly tinted with yellow. The raffinose is attributed to a preëxistence in the beet.

According to STAMMER,[3] the odd crystallization frequently noticed in sugars obtained by the SCHEIBLER process is due to the influence of raffinose found in the mother liquor. AULARD[4] considers that this abnormal crystallization of the sugars obtained by the separation method is due to the influence of the calcic salts. If these are removed from the massecuites and the raffinose is allowed to remain, the crystallization that follows is perfectly

[1] Z., 52, 260, 1902.
[2] Z., 50, 978, 1900.
[3] La. S. B., 19, 411, 1891.
[4] La. S. B., 19, 412, 1891.

normal. There has been no satisfactory explanation of this issue. In fact, the sugars obtained by the strontia process do not crystallize in the same shape as those obtained by numerous other processes of molasses desugarization. According to SCHAAF,[1] the crystals of sugar from molasses are always in groups that depend upon the symmetrical axis, and appear to be stretched in the direction of their length.

Langen and Felde process.—Baryta was the first chemical substance employed for the desugarization of molasses. In 1849 DUBRUNFAUT and LEPLAY had already obtained very satisfactory results with it. The process does not essentially differ from the lime or strontia methods. As regards the actual extraction of sugar from molasses, it offered fewer difficulties than the other process. The witherite or barium carbonate, however, is too expensive, and is about the only mineral that can be utilized for this purpose; furthermore, the difficulties of regenerating the baryta residuary products are very great.

In the BEAUFFRET process, molasses containing 50 per cent of sugar is heated to 45° or 50° C., and a 60 per cent baryta water is prepared, which is heated to 90° C. These liquids are very thoroughly mixed, in proportions determined by experience, and allowed to settle. After five minutes there will be formed a white precipitate of saccharate of barium, containing one molecule of baryta to one molecule of sugar. The quantity of baryta to be added is calculated from experience upon the following basis: 1 kilo per kilo of ash + 0.5 kilo per kilo of organic substances + 1.1 kilo per kilo of sugar. The saccharate of baryta thus formed is separated from the mother liquor in filter presses, and is then diluted and sent to the carbonatation tanks as a milk of saccharate of baryta. The carbonate of baryta is regenerated in the form of baryta in a reverberatory or recuperating furnace.

By various modifications of the original idea, LANGEN and FELDE have brought to light a method which, although it may not give remarkable profits, has been tested with encouraging results. In this process the baryta sulphate is the starting point. This heavy spar is pulverized and mixed with powdered coal and oil, and is brought to red heat in a furnace. A sulphid of barium is formed, which is changed into a hydroxy-sulphid of barium. This is brought in contact with molasses and heated. There follows a

[1] Z., 33, 699, 1883.

precipitation of saccharate of barium and a sulphydrate of barium. The first is insoluble; it is separated by filtration, and the filtrate contains the impurities and the sulphydrate. A washing in the filter presses follows, and the saccharate thus obtained is used during second carbonatation. The filtrate is submitted to a carbonatation, and the baryta precipitates in the form of a carbonate, liberating sulphuretted hydrogen, which is collected in gasometers, and subsequently burned in special furnaces, being thus transformed into water and sulphurous acid. The latter is used to decompose the carbonate of barium previously obtained with formation of sulphite of barium. This solution is evaporated to complete dryness, then incinerated and calcinized with coal (in the same kind of a furnace as was employed for the sulphate) to obtain a sulphid used during the manufacturing process. According to a well-known expert,[1] the two most difficult phases of this process are the carbonatation of the mother liquors of the sulphydrate of barium and the incineration of the sulphite of barium solution. It is claimed that the juices thus obtained have an exceptional purity, sometimes reaching 97.7 in the massecuite.

STERNBERG[2] proposed another method for passing from the sulphydrate to the sulphite of barium, namely, by the simple action of sulphurous acid upon the filtrate of barium saccharate. Sulphur will be simultaneously precipitated. There follows an evaporation to complete dryness, and a roasting of all the products. There will be formed sulphurous acid and barium sulphate, which may be regenerated, as already explained. Numerous other barium processes have been tried, but none of them has given practical results.

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[1] SAILLARD, Technologie, p. 196, 1904. [2] Oe.-U. Z., 27, 566, 1898.

CHAPTER V.

DESUGARIZATION OF MOLASSES BY MEANS OF LEAD SALTS AND ELECTROLYSIS.

There are several kinds of lead saccharates, such as bi-saccharate and tri-saccharate. The first of these is soluble in acetate solutions of lead, but not in water; the latter is slightly soluble in water. BERZELIUS[1] obtained the lead saccharate by adding a lead oxid in excess to sugar solutions. In this manner all the sugar was separated. In 1850 DUBRUNFAUT made many unsuccessful attempts to invent a process for extracting sugar from solutions by means of lead. To WOHL must be attributed the only method that has met with any success.

Wohl process.—By this method of working, the residuary molasses is diluted with 80 per cent of water, and yellow lead oxid is added, so that the proportions are 150 parts oxid for 100 parts sugar. The mixture is passed through a grinding mill, such as is used for mortar. After this operation has lasted about 20 minutes, the liquid paste is run into reservoirs, where it remains for one and one-half or two hours. The mass solidifies, and all the sugar after that interval has entered into combination. The product is subsequently diluted and run through a filter press. The resulting cakes are carefully washed, first with warm water, to eliminate the soda and caustic potash resulting from the chemical reaction, and then with water at 75° C. If these caustic solutions should come in contact with the ordinary filtering cloths, the latter would soon be destroyed. At one time it was proposed to cover the frames of the filter-presses with asbestos cloths, but such methods are too expensive. The saccharate is diluted in water, and then very thoroughly carbonatated; filtration follows, and a filtrate of a purity of 99 is obtained. The residuum of lead carbonate from the presses is regenerated into oxid of lead, using for the purpose

[1] LIPPMANN, Zuckerarten, II, 777, 1895.

one of the existing processes. It is this regeneration of the lead oxid that has been the cause of considerable difficulty. KASSNER[1] has proposed to heat this carbonate with oxid, bioxid, sesquioxid, hydroxid, or nitrate of lead to regenerate the oxid of lead that it contains.

WOHL[2] has been able to regenerate the lead oxid in a moist condition, thus doing away with all the complications of a regenerating furnace. The process is based upon the principle that insoluble basic carbonate of lead, precipitated by the carbonatation of the saccharate, instantly loses, at the ordinary temperature and in the presence of an excess of potash or caustic soda, all of its carbonic acid, and by observing certain determined conditions one is able to precipitate the active oxid. The same chemist[3] later proposed that this solution be used for the precipitation of sugar, which method was easier and more simple. Then other improvements were made in order to obtain a purer saccharate.

It is to be noted that formerly one of the objectionable features of the WOHL process for desugarization of molasses was, that foreign substances, such as raffinose, would precipitate at the same time as sugar. This difficulty is overcome by heating the solution of molasses to 80° or 90° C. with a lead saccharate, to which a small quantity of alkali has been added. In the precipitate thus obtained there is very little sugar, and it may be mixed with the filtrate at 40° Brix., which is obtained from the subsequent precipitation of sugar from this molasses solution and carbonatated. A perceptible decoloration of the molasses takes place during this preliminary epuration. The carbonate of lead obtained by the carbonatation of the mentioned residues may be redissolved in a wash of caustic potash, filtered and used for the precipitation of the lead saccharate. By this means mechanical impurities are eliminated that would otherwise accumulate in the cycle of the manipulations connected with the process

Certain facts were noticed which led to new changes in this method. If molasses is mixed with caustic potash and yellow lead oxide in the proportions corresponding to the formula $C_{12}H_{22}O_{11},PbO,KOH$, after some time a part of the lead and a part of the sugar will crystallize as an insoluble lead saccharate, and can be separated while another part of both compounds remains in the solution as a soluble lead saccharate. If a new quan-

[1] N. Z., 40, 211, 1898. [2] C., 6, 228, 1897. [3] D. Z. I., 25, 598, 1900.

tity of molasses and lead oxid is added to this solution, a new quantity of insoluble saccharate will crystallize, etc. The very presence of the soluble lead saccharate seems to favor the separation of the crystallized compound. It has also been proposed to change the residue of the mother liquors, rich in potassic salts into a plastic mass by the addition of lime, instead of burning it in a furnace. This mass is heated in special retorts, and the liberated ammonia is collected. By the original method of working,[1] the rapid precipitation of the bi-saccharate of amorphous lead was such as to carry down all the impurities. Through the new process, that is to say, by the successive additions of molasses and epurating agents, there is produced a mass from which the mother liquors are easily separated.

Attention may be called to yet another improvement in the manner in which the carbonatation of the saccharate of lead is conducted. By the process as first conducted, the carbonatation was complete and was pushed to neutrality. An objectionable feature of this procedure was the liberation of foreign substances originally precipitated by the lead. These were then returned to the sugar solutions, which thus became very pure, and their subsequent working was made more difficult. By the later process[2] the carbonatation ceases when the saccharate is decomposed and the sugar liberated. This mass is filtered and washed. The hydrocarbonates of lead are mixed with water and carbonatated again to neutrality. To eliminate the calcic carbonate contained in the precipitate, a small quantity of hydrochloric acid is added just before carbonatation is terminated. The lime then passes into the solution. No particle of lead carbonate is decomposed by the acid added.

Kassner[3] proposed to extract the sugar contained in diluted solutions, molasses, etc., by a filtration through filter-presses, or through filtering plates placed one over the other, on which is a layer of paste composed of oxid or hydroxid of lead and sugarate from a previous operation. The sugar combines with the lead oxid, and the filtrate obtained contains very little sugar.

While the Wohl process is very interesting from a theoretical point of view, its working in practice is too expensive, and several factories that gave it a fair trial are said to have abandoned it on that account. There need be no apprehension as to the use of lead salts and their toxic properties, provided the various manipulations

[1] Z., 50, 619, 1900. [2] D. Z. I., 25, 1769, 1900. [3] Z., 48, 498, 1898.

are conducted by competent persons; for then lead is not even found in the residuary molasses, and, consequently, cannot be in the sugar. While the carbonate and sulphate of lead are insoluble, these strontia, baryta, or lead processes should hardly be attempted in any beet-sugar factory unless especially watched by a well-conducted laboratory and a staff of chemists.

Electrolysis.—No serious efforts have ever been made to epurate residuary molasses by electrolysis and electrodialysis. What was said upon this subject, under the caption of Electrical Epuration of Saccharine Juices, also applies in this connection.

CHAPTER VI.

OTHER MODES OF MOLASSES UTILIZATION.

Use of molasses for distilling.—In Europe, most of the residuary molasses from beet-sugar factories is used for the manufacture of alcohol. Hence the author has repeatedly urged that new enterprises should begin with a distillery, using the beets from experimental patches within a radius of several miles of the site of the proposed factory. If these roots yield alcohol in certain proportions, the sugar content must be satisfactory. The sugar plant can then bring the distillery into practical use for disposing of its residuary molasses. It is to be noted that when a beet-molasses contains a low percentage of salts it will not readily ferment, and this is the theoretical explanation made in the case of osmosed molasses. Under the influence of a soluble ferment, a zymase contained in the yeast and known as sucrase, the saccharose is split into dextrose and levulose, and these two sugars are transforme into alcohol, carbonic acid, and water through the action of the yeast cells.

From the distiller's standpoint, the sugar of the molasses is the most important element of this product, but, besides the sugar, there are generally other substances, such as dextrose, etc., which result from numerous alterations of the juice during some phase of the manufacture, and all these play an important part in the yield of alcohol obtained from a given weight of molasses. On the other hand, the raffinose helps to increase the polarization of a molasses and contributes little to the alcohol yields. Through the sucrase, the raffinose [1] is changed into levulose and melibiose. As the latter cannot be split up into sugars that will ferment, the raffinose would contribute very little to the alcohol yield

When the molasses is to be rapidly fermented there can be no objection to a slight acidity, as it is to be slightly acidulated before

[1] Dejonghe, Alcool, 1, 211, 1899.

fermentation anyway. On the other hand, if the residuum is to be kept for a considerable time, the existing acidity might be responsible for considerable sugar losses through the action of varied micro-organisms. This is especially the case when proper attention is not given to cleanliness in the factory, especially in the molasses tanks or receptacles. In most beet-sugar factories, the residuum molasses left after the campaign remains either in the large crystallizing tanks or in special receptacles. The rooms where it is kept must be warm, otherwise the product will become very thick and sticky during the winter. It must then be reheated by steam in these reservoirs when it is intended to ship the product, which is very objectionable when it has to be filled into barrels, for, in a diluted and hot condition, it would leak out.

When it is intended to keep fresh molasses in barrels, it is collected and diluted to 42° Bé. as soon as it leaves the centrifugal, and the product runs into a distributing trough, which may allow several barrels to be simultaneously filled. This trough should not be too long, or the residuum will thicken. After the barrels have been filled they are weighed, their outer hoops being well tightened if necessary. Under no circumstances should the empty or filled barrels be left exposed to the sun. In case the molasses is to be shipped in special cisterns it is pumped up to them, or, if the molasses reservoir is at a certain elevation, it falls by gravity. Generally, the product is brought to the molasses distillery in cisterns placed on suitable car trucks.

Industrial usage of molasses.—It is customary to add molasess to the dye-wood extracts, though just why this is done is not clear. The factories making logwood and other extracts add the molasses, that the dyer need only dilute the mixture to have exactly the proportion in which the product is to be used. The quantity of molasses thus added frequently reaches 40 per cent of the final product obtained. This industry appears to be largely monopolized in France and Germany. The mixture in question is obtained under the following conditions: The coloring substance is concentrated so as to form a juice of a density of 20° to 25° Bé., the methods of extraction and evaporation being exactly the same as are used in extracting the sugar from the beet (with the exception of the epuration). The juices are then mixed with different substances, which give to the black any special hue desired. The molasses is added in measured quantities, and the mixture is sent to a vacuum pan having an interior agitating device. The mass is concentrated

until it becomes very viscous, and is then run into moulds, where it solidifies in very hard cakes. It is to be noticed that the large proportion of molasses increases the fluidity of the product even at low temperatures.

For shoe-blackings.—The quantity of molasses consumed by the shoe-blacking industry is comparatively small, but yet it has its importance. It is a well-known fact that concentrated sulphuric acid has an enormous affinity for water, and will even remove the water molecules from many compounds that contain elements of water. Sugar, for example, groups with its molecule the element of six molecules of water combined with six atoms of carbon; sulphuric acid will remove all the hydrogen and oxygen, and leave carbon as a final product. When molasses is mixed with concentrated sulphuric acid the mass will boil over and turn black, and the final product will simply be a pasty carbon which is very finely divided. It is washed to remove the acid in excess. Some ivory-black is then added, and a certain quantity of various substances which give a fatty compound.

Usage of molasses for cattle-feeding.—The subject of molasses utilization in cattle-feeding has been fully considered in a previous volume.[1] It was pointed out that the principal value of molasses was due to its sugar. Also the salts stimulate the digestion, the result being that an exceptional amount of forage is eaten. It is not advisable to use molasses on the farm in the condition in which it leaves the factory, and, owing to its heavy, pasty condition, it is generally mixed in various proportions with peat, straw, etc. There are now special establishments undertaking to furnish these combinations to the farmers, and therefore their preparation is not usually attempted in the beet-sugar factories.

Experience shows that in these preparations the temperature of the molasses should not exceed 80° C.; otherwise the cooling would be too slow, and, as many substances would be burned even at that temperature, a lower one is sometimes desirable. Whatever be the method adopted, the mixture should be spread out in thin layers, so as to cool before being sacked. When these cattle-foods are made, it is better to use fresh rather than stored molasses. Every precaution should be taken to keep the product thoroughly dry, for when moist it undergoes organic changes which may be very harmful to cattle or horses. The authorities upon the subject point out that the molasses, when it is to be combined for feeding

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[1] See Ware, Cattle-feeding, Phila. Book Co.

purposes, should not be reheated by means of steam-injectors, but with closed steam coils. Forages that contain molasses at a concentration of less than 78° Brix. have no keeping powers.

Usage of molasses as a fertilizer.—It has been frequently suggested that there would be important economic advantages in using molasses as a fertilizer, but this involves a complete loss of the 50 per cent of sugar they contain. Under certain conditions, this is the only use to which it can be put. A large percentage of the plant foods extracted from the soil during the beets' development are thus returned; but, besides saving in food, the same results are realized when it is mixed with beet-pulps and given as food to cattle. VIVIEN [1] states that, when the residuum is utilized as a fertilizer, about one-half a ton is necessary per acre, it having been first diluted with one-seventh water. A solid cake may be made with molasses by combining 100 kilos of slaked lime with 200 kilos of molasses, and thus a powder is obtained that may be readily spread over the surface of the soil. MEHAY [2] made the same mixture, but used quicklime.

As a fuel.—It may so happen that the residuary molasses has no market, either for distilling or other purposes, and at the same time the cost of fuel is exceptionally high. This is of frequent occurrence with cane molasses in tropical countries, but is rarely the case in those climes where sugar is extracted from the beet. The residuum is sometimes burned in special furnaces, as, for example, at the NAGH-HAMADI (Egypt) sugar factory. Directly in front of the boiler is placed a long brick furnace. The molasses is distributed through a pipe upon the slanting bottom of the furnace. This product has a tendency to flow away from the boiler; but the already burning molasses communicates the flame to the fresh product, and there result masses or crusts of carbon, which soon give the requisite heat to bring the boiler under pressure. These crusts are entirly consumed, and there remains an ash consisting of the salts the residuum contained. The ash, which is pushed down and is removed from an end door, may be advantageously utilized as a fertilizer.

According to MATIGNON,[3] beet molasses has a caloric power of 3156 calories. MAIGNARD [4] also has met with some success in the preparation of a molasses fuel. The residuum is concentrated so

[1] S. I., 9, 471, 1875.
[2] S. I., 10, 255, 1876.
[3] Second Congress, 1, 293, 1897.
[4] D. Z. I., 27, 1813, 1902.

as to obtain a nearly compact mass, but before its final solidification porous substances are added which absorb the water. The product is compressed into bricks, which may be kept for a long time. The idea of combining molasses with coal-dust, and then making bricks out of the conglomeration, has also been suggested.[1]

Other usages.—Besides the utilization of molasses in the ways mentioned in the foregoing, there are so many others that the mere mention of them would take considerable space. Among them may be cited its use in disinfectant solutions to be sprayed upon plants. The sticky or adhesive property of the product makes the chemical insect-destroyer to stick to the spot where it is most needed.

A French[2] inventor states that, when molasses is combined with a decoction of any product containing tannin or with lime, the product has considerable industrial value. For example, if 75 to 80 parts of molasses are heated nearly to boiling point with 20 to 25 parts of lime, there will be obtained, on cooling, a product sufficiently adhesive to take the place of colophony, or adhesive grease. By boiling during a certain period a mixture of 2 parts of molasses with 3 parts of lime, the compound will form an excellent substitute for dextrin and gum arabic. If 30 to 35 parts of lampblack are mixed with 70 to 80 parts of molasses, to which are added 1 to 2 parts glue and wood-shavings containing tannin, the mixture may be used as a fatty blacking. From a tannin and molasses combination, to which has been added a lacquer solution, and which has been subsequently treated by a patent process, a product is obtained very analogous to caoutchouc, and may be used as a cheap substitute for rubber.

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[1] Bull. Asso., 5, 190, 1 887. [2] S. B., May, 1899.

CHAPTER VII.

RESIDUARY WATER.

Quantity and nature.—Enormous quantities of water are needed in a beet-sugar factory. As early as 1851 BRIX declared that 85 cubic meters of water were needed for the sugar extraction, and 2610 cubic meters for the condensation, for every ton of beets sliced. Owing to the introduction of new machinery and processes since that time, those figures would now be misleading. At the present day the water consumption for working by diffusion is 250 to 300 per cent of the total weight of beets sliced; and for condensation the modern evaporating plant, including the vacuum pan, requires from 350 to 800 per cent. The total quantity of water necessary is 1000 per cent of the weight of the beets worked, but this limit is frequently exceeded.

The reutilization of water is a difficult problem to solve; hence it is important, when selecting a site for a sugar factory, to have water in abundance, and of a quality to meet all the demands of the sugar-manufacturing process. For the diffusion, a water of the highest possible purity is required; and for the boilers it is essential that the water shall not contain those compounds which form deposits or incrustations. For the evaporation a larger volume of comparatively fresh water is needed, and for the STEFFEN separation it should be as cold as possible. Some residuary waters cannot be used a second time, and must be disposed of without injury to adjacent property. In Europe there is no issue at the present day that is of greater importance than this, and yet it has not been entirely solved to the satisfaction of all interested.

The final residuary waters of beet-sugar factories are of most varied composition. They include:

1. The waters from the washers and the hydraulic carrier; these contain considerable earth, beet and vegetable wastes, and sugar and micro-organisms in great number, some of which are said to be destructive to beet cultivation.

2. The waste from diffusion battery, holding in suspension considerable quantities of cossette-ends, sugar, albumin, and micro-organisms.

3. The sweet water from the cossette presses presents the same general characteristics as the waters just mentioned, but at a higher degree.

4. Sweet waters from charcoal filters in a few factories where these continue to be used. These waters contain more micro-organisms than any of the others, owing to the fermentation to which they are submitted and to the sugar they contain.

5. Water from the carbonic acid waters, containing carbonic acid, carbon oxid, and sometimes sulphurous acid and ammonia.

6. The ammoniacal waters from the multiple effect, etc., which also frequently contain traces of sugar.

7. Water from the condensers, containing the same substances as already mentioned, but in very small proportion.

8. Water from the purgers of the machines, which are highly charged with fatty substances.

9. Water from the boiler cleaning, holding in suspension the boiler scalings, and frequently retaining a small quantity of decomposed sugar, oils, etc. These waters are very hot.

10. Waters from filter cloths and sugar-bag washing, containing a fraction of sugar, but micro-organisms in large quantities.

11. The dirty waters which are the outcome of washing and cleaning the factory, and combine the characteristics of all the other waters.

12. The overflow water of all water pumps.

Necessity of epuration.—Waste water from beet-sugar factories has not as yet been much discussed in the United States, but it is only a question of time when many litigations relating to the subject will be argued in our courts. As these frequently will involve considerable sums of money, and even go so far as to force certain factories to shut down in the midst of their campaign, leaving thousands of tons of beets unworked, the money value of which will be a loss to the manufacturers or farmers, it is important to consider the residuary-water question carefully. The fact is, the problems of the epuration of residuary water from beet-sugar factories is far from finding a solution. In most countries there is much litigation occasioned by river pollution. In France there is a law prohibiting the emptying of waste waters from diffusion batteries

into cisterns which in any way connect with a neighboring stream or river, waters from the beet washer being excepted.[1]

Residuary waters from beet-sugar factories are not hurtful to the health of man or beast, but they may bring about unpleasant transformations in small streams. To fish, these waters are directly very inoffensive, and it is only the development of certain vegetations that has an injurious effect when they entèr into decomposition. The organisms responsible for these fermentations are to be found in all residuary waters of beet-sugar factories. The *beggiatoa alba* forms a white deposit upon the scums of these impure waters in the state of putrefaction. The *Sphærotilus natans* also lives in very impure waters, but is not susceptible to putrefaction, and the *leptomitus lacteus* is to be found in still purer water. By the presence of these three forms of algæs the condition of epuration of a water may be approximately judged. But the bacteria, in assimilating organic substances not subject to putrid putrefaction, change them into protoplasm that is likely to putrefy, and will decompose as soon as the level of the stream or river is sufficiently low to leave it exposed to the air. In order that these organisms may continue to develop, it is necessary that the waters themselves be of a certain purity.

Mez[2] concludes that it is not rational to demand that the waters emptied into streams should not produce a certain vegetation; for, when the sugar campaign begins, no factory has the time or the facilities to push the epuration of its waste water to that limit. What might be demanded, is that the epuration be continued so that the *beggiatoa alba* can no longer develop, which within itself would indicate that the waters will no longer putrefy. It must be remembered that the *leptomitus* is found mainly in relatively pure waters, and its development generally indicates that the epuration has been effectual; on the other hand, the *Sphærotilus* is found in impure water, while the *beggiatoa alba* indicates putrefaction, and consequently the presence of these two vegetations indicates a water that has not been sufficiently epurated.

The vegetation of the algæs in certain cases may reach such a state of development that the streams are simply overrun with it. Water mills may even cease running through its influence. The explanations of this differ. On the one hand, it is claimed that the albuminoids in excess are responsible; on the other, that it is

[1] La. S. B., 23, 91, 1894. [2] C., 7, 705, 1889.

the sugar contained in these residuary waters that does the harm. From numerous investigations it would appear that sugar is more objectionable than any other foreign substance. Without doubt, the sulphuretted hydrogen thrown off by the putrefaction of the algæs will kill fish, and therefore is a direct poison; furthermore, it deprives water of a certain quantity of oxygen, as it oxidizes itself with liberation of sulphur, and this also is destructive to fish. The absence of oxygen is the main cause of the difficulty, as in these waters there are but few substances which act as toxics. According to WEIGELET,[1] mineral substances will kill tench and trout when in the following proportions: Calcic hypochlorid, 0.0008 to 0.0005 per cent; sulphurous acid, 0.00005 per cent; sulphuretted hydrogen, 0.01 to 0.001 per cent. Hydrochloric, nitrate, and sulphuric acids will not be fatal within the limits of 0.1 per cent.

HULWA points out that the degree of purity of water does not determine its suitability for fish. In pure water, fish could not thrive, as they need impurities of a special kind. The mud and impurities of swamps may create the very best conditions for the support of carp, eels, etc. It is exactly with this idea in view that there are often thrown into ponds various kinds of household wastes to feed the fish, not directly, but with the micro-organisms which result from certain changes in such material. HULWA claims that the mortality among fish may be due to epidemics that have nothing to do with the nature of the water. Sewer waters are objectionable when they kill the aquatic vegetation. This vegetation and the fauna have a double object in view, that of bringing about a putrefaction of the water and of feeding the fish. Mollusks and micro-organisms feed upon these residues. The question, as a whole, demands considerable thought. If the point at which the water is emptied into the river is far enough from the place where it is to be utilized, the contact of the air, etc., effects a natural epuration. There are evidently exceptions to this rule, as when the stream is small compared to the quantity of waste water it receives, in which case the pollution attains its maximum proportions, and under no circumstances should the local authorities tolerate such an abuse.

Classification of residuary waters in accordance with their necessary epuration is an important question to be considered, and, as previously pointed out, some waters may be thrown into the river, for example, the water that overflows from various pumps

[1] S. I., 40, 379, 1892.

of the factory or from the water reservoirs, and these waters should not be mixed with residuary water. On the other hand, some waters need only to be exposed to the air, cooled, and then thrown off, as is the case with the water from the condenser, carbonic acid washer, and that blown off from the boilers. Such waters contain too little oxygen, hence the importance of their aeration. The waters from the beet-washer and the hydraulic carrier only need to be decanted, as their mechanical impurities are thus readily separated. All the other waters must be epurated, and the methods are of three different orders—mechanical, chemical, and biological.

It is evident that there is an advantage in an intelligent classification of the factory residuary water. Furthermore, under certain circumstances, the same water may advantageously be used several times; water from the condenser, for example, may be used in the flues, or hydraulic carriers, for the beets, and the waste from the diffusion battery may be employed for working by the dirty-water method in the battery itself.

Mechanical epuration.—Under another caption has been given the method of cooling and aerating water. The mechanical impurities favoring fermentation must be separated from the waste waters of the washers, diffusion battery, and cossette-presses. There are many different arrangements for separating these suspended pulp or beet particles, among which mention may be made of the Laass[1] separator, which is composed of a rotating drum, holding a movable comb that works between the bars of a curved grating connected with the beet-washers. Another grating with straight bars is placed above the revolving drum. The teeth of the comb remove the free pulp from the first grating. This pulp falls off easily, and the working is greatly facilitated by the alternating motion given to the bars of the arrestor by a cam receiving its motion from the rotating drum. Another arrangement consists of a brick-and-cement-lined pit, through which flows the dirty water to the exit at the bottom, the larger ends of beets being arrested by a suitable grating, and removed by rakes attached to chains. Another pulp and broken-beet arrestor consists of a large metallic filtering cloth, placed at the bottom of a pit, through which circulates the water from the washer. Here again the deposits are removed with rakes. In another combination, instead of the rakes, scrapers are used, alternating with brushes, which force the deposits

[1] Z., 51, 645, 1901.

to the upper inclined portion of the metallic filtering cloth, from which they fall into a spiral. In case of beet-washers the mesh is 4 to 5 mm., and for the water from pulp-presses 1 to 2 mm.

Another arrestor consists of a large drum, the sides of which are perforated. The drum forms, with another metallic cloth, a sort of trough, one side of which is perforated. Water passes through the holes, while the drum during its revolution raises the solid particles, which are subsequently removed by suitable scrapers. Yet another arrestor may be mentioned, which consists of a box, at the bottom of which is a metallic filtering cloth. Four horizontal arms, with scrapers, remove the deposits when they reach a certain height, and an apparatus with a backward and forward motion throws them into a carrier. It is claimed that 2.5 per cent of the total weight of the beets washed are lost without the use of these arrestors. From pulp-presses also 0.3 per cent is collected. This free pulp from presses may be mixed with pressed residuum pulps.

Chemical epuration.—No chemical is known that will satisfactorily purify the residuary waters from a beet-sugar factory, and, notwithstanding the numerous experiments in this direction, lime continues to remain in use as giving the best results. Lime is added to decanted waters; but, as this addition is made without method in most cases, the results obtained are disappointing. Now and then a few handfuls are simply thrown into the canal connecting with the main stream or river, and the lime is slaked here and there as it may happen to fall. The arrangements for milk of lime distribution through a regulated valve are gaining in popularity.

A special appliance has been used by SCHLICHTER[1] for mixing the residuary water from beet-sugar factories with epurating agents. It consists of an inclined trough, divided into several compartments by means of vertical divisions two-thirds of the height of its sides. The bottom of this receptacle has an inclination that is the reverse of the axis of the trough. Under these conditions the mechanical impurities tend to deposit themselves on the lower side, notwithstanding the intensity of force of the current of water. The vertical divisions reach nearly to the bottom, thus forcing the water to follow a zigzag direction, which greatly facilitates the mixing of the residuary water with the substance used for its epuration. The waters thus mixed with lime are left to settle in large tanks, from

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[1] C., 11, 779, 1903.

which they flow into the river, and are more or less alkaline. WEIGMANN'S[1] experiments show that lime-epurated water, which had been subsequently filtered and still retained an excessive alkalinity, contained no micro-organisms after having settled for three to four weeks. Other waters, that had been neutralized by carbonic acid and exposed to the air, contained 25,000,000 of these lower forms of life in a cb. cm.

Notwithstanding the fact that the water running from the decanting tanks may be perfectly clear, it is not pure water; for it contains all the substances dissolved, mainly sugar, which will ferment and putrefy. Chemicals will not act on these substances and the residuary waters can be rendered alkaline only through the use of milk of lime, and thus, in a measure, the fermentation, or putrefaction, is retarded, which, however, is of very doubtful advantage.

BODENBENDER recommends that these settled, limed, alkaline waters be passed over a series of steps forming a waterfall; the aeration is then more complete, and an oxidation of the organic substances necessarily results. For this liming, HULWA proposes a process consisting of three distinct operations. The lime is added to the water, and then, depending upon the composition of the water being treated, there is added a preparation of iron, magnesia, lime, and cellulose, the latter being prepared by a special process. The precipitate is separated, and the strongly alkaline filtrate is submitted to a carbonatation. A second filtration follows. Then a small quantity of sulphurous acid is added, which acts as a disinfectant, and helps to keep the waters in this condition of purity.

Among the chemical processes that have met with reasonable success in residuary-water epuration may be mentioned the use of iron salts, suggested by VIVIEN[2] in 1878. The most successful method is that of LIESENBERG, in which an iron salt is used with an excellent epurating effect. If such salts have not been generally adopted for this special purpose, it is due to the fact that the ferric preparations hitherto used have been too expensive, and, furthermore, have not been sufficiently active in their effects. The salt giving entire satisfaction is a sodic ferrite having the formula $Na_2F_2O_4$. To produce this chemical, an equal weight of soda is added to pulverized iron-ore in a special smelting-furnace,

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[1] VIBRANS, Abfallwasser, 13, 1899. [2] Bull. Asso., 11, 132, 1893.

and a reaction follows. If a ferric alumina mineral is used, one obtains at the same time an aluminate of soda. The residuary waters are first treated with milk of lime until there is a slightly alkaline reaction; then ferric or ferric-aluminate of soda is added, which decomposes with the liberation of hydroxid of iron, of soda, and finally of alumina. Ferric hydrates and alumina have an energetic action in precipitating most of the organic combinations by stopping the formation of sulphidric acid. The water is decanted from the precipitate.

The mixing should be done in a special receptacle, having at its bottom a revolving shaft with arm attachments. Upon the shaft are scoop wheels, taking up and throwing out always the same volume of chemical solution, which subsequently flows into the receptacle containing the residuum water. It is pointed out that the ferric salt under consideration gives far better results than can be obtained with ferric sulphate. This process was considerably in vogue in Germany about ten years since, but for some reason it has now become obsolete. Like most of the methods of so-called epuration, it has no action on the albumen and sugar, the most objectionable elements in residuary waters, and this holds good for all processes based on the combination of disinfectants.

Among the other chemicals used, mention may be made of ozone. Residuary-water epuration by the OTTO[1] method consists in the use of several injectors, which closely mix the water with ozone. This combination passes into a separating compartment, in which the ozone and the water are divided, and then conducted into a larger receptacle. The ozone enters from the bottom, but the water falls from the top and again comes in contact with the ozone. In order to increase the surface action, the water is made to circulate over a series of obstacles, upon which it is finely subdivided. The same fault may again be found with this process regarding the lack of action upon sugar and the albuminoids, as ozone is without such action. This process of epuration has, nevertheless, had a certain vogue in sugar factories.

Mention may also be made of an electrical process. PFINGSTHORN[2] has suggested accelerating the oxidation by electrical action upon water; the oxygen liberated will be in a native state and very powerful in its action, much more so than when forming part of the composition of the air. The experiments were carried

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[1] Z., 53, 442, 1903. [2] S. B., May, 1889.

on with a 7-horse-power dynamo. The two poles of the dynamo were put in communication with the pencil of platin wire, and this was submerged in water that had been submitted to a preliminary lime epuration. In order to prolong the action of the liberated oxygen, it was proposed to accomplish this electrolysis in large hollow columns. The process was too expensive, and was subsequently abandoned. The HERMITE[1] electrical method consisted in using an electrolyzor holding water to which had been added some chlorid, and allowing the production of an oxygen-chlorin compound on the positive pole and a metallic oxid on the negative pole.

Biological processes.—From what has been said in the foregoing, it is clearly shown that the numerous processes of epuration tested have not accomplished the purpose in view. The fermentation and putrefaction continue to take place when the suitable occasion presents itself, and, after their work is accomplished, these complex substances become simply mineral and are harmless. So the idea is suggested: Have we not here the very process needed?

Apparently, it was MUELLER[2] who first suggested that fermentation and putrefaction should be the rational process for epuratign residuary waters of beet-sugar factories. This process demanded a series of tanks, each with a capacity for holding the waste water for twenty-four hours. To these waters, warm water from the condensers is added, so as to obtain a condition favorable for fermentation, and, in order to obviate all possible loss of caloric, the tanks are covered with poor heat-conductors. Fermentation does what the chemical agents could not do,—it eliminates the albuminoids and sugar. The waters are subsequently filtered in coke-and-sand filters. The practical experiments made with this process showed[3] that during the winter the fermentation is very slow, on account of the difficulty in maintaining the favorable temperature. The process is expensive on account of the numerous reservoirs needed, and the liberated gases from the tanks are decidedly objectionable.

ELSASSER proposed to circulate these residuary waters upon lands, and allow them to drain through the soil, but this plan demanded enormous areas, and on that account was impracticable in most cases. The PROSKOWETZ process, which has been widely and successfully adopted, is a variation of the method just mentioned. The best installation for description is that of the 400-ton

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[1] S. B., July, 1899. [2] Z., 29, 85, 1879.
[3] VIBRANS, Abfallwasser, 17, 1899.

beet-sugar plant at SADOWA,[1] Bohemia, where the method is in practical operation. The water from the factory is received in a decanting ditch, *A* (Fig. 221), where the heavier impurities are deposited, and from thence it passes into a series of decanting receptacles, *C*. During passage the water necessarily cools, and then flows upon the first draining land, *D*. Upon this field the drains are placed perpendicular to the ditch that separates *D* and *E*.

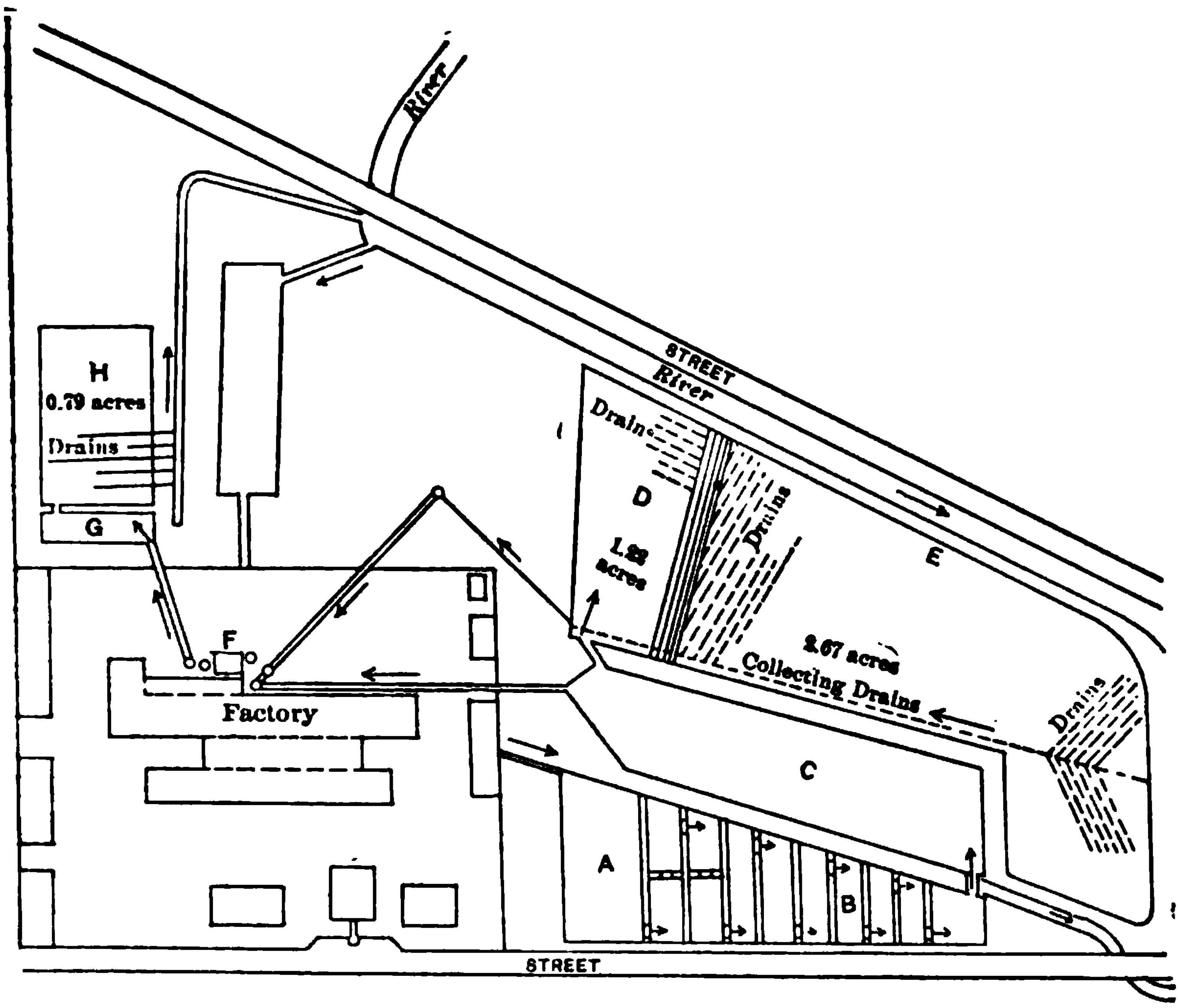

FIG. 221.—PROSKOWETZ Process of Biological Epuration of Residuary Water as Applied at SADOWA.

These drains have a diameter varying from 80 to 100 mm., and are placed at a depth of 0.47 meters below the surface of the soil. The spacing between the drains is 0.70 meters. The subsoil and the draining lands of *E* and *H* consist of about 0.75 meters of humus, and then a layer of slightly argillaceous earth. From practical experiments made, it is shown that the field, *D*, might have been half the size it actually is, and yet the ultimate results would have been the same. The water is collected in the ditch between *D* and *E*, and is slightly acid. From here the water flows onto the field, *E*,

[1] Z., 48, 890, 1898.

where the drainage is accomplished at a much greater depth. The drains in this case have a diameter of 80 mm., and are placed about 1.25 meters below the surface, with a space of 2 meters between them.

The waters unite in the collecting drains, and then flow to the factory in an open canal. There they are mixed with a small quantity of lime, and then flow into the decanting tanks, *G*, where the insoluble calcic compounds may deposit the combinations of the products of decomposition of the water during drainage with lime. The water runs off by an overflow upon the draining land, *H*, in which there are two series of drains, some of which are 0.50 meters and others 1 m. below the surface. The first have a diameter of 80 mm., and their spacing is 0.70 meters. In the others the diameter is 100 mm., and their spacing is 2 meters. The water then runs into the river in a most thoroughly purified condition. There are numerous variations from this standard arrangement which need not be given.

HERZFELD [1] criticizes the PROSKOWETZ process for waste-water purification. He says it is impossible to obtain a thorough epuration when water contains such a small percentage of sugar in solution. With modern distilling appliances, the final wort retains ten times as great a percentage of sugar as does the sugar-factory residuum wastes, yet it escapes fermentation. Fermentation of the waste water in question is considered dangerous to health, while, when not fermented, it is not harmful. According to MALANDER, it must not be lost sight of that in this case there is no question of alcoholic fermentation, and that the word of fermentation used for this process is misleading. The micro-organisms that cause the decomposition of the residuary water in the process under consideration have nothing in common with a ferment, and may perfectly produce the phenomenon sought, even when the albuminoids and sugar are contained in the waters in very small quantities, just as some micro-organisms are able to thrive in distilled water that is apparently chemically pure.[2]

In the usual method of water epuration, several fields located at different elevations are necessary; otherwise it becomes necessary to pump the filtered water from one field to the other, so that the filtration may complete itself. The first-mentioned arrangement is not possible everywhere, and the objection to the second plan is

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[1] Z., 49, 992 and 996, 1899. [2] S. B., March, 1901.

that the water circulation is confined to areas around the wells where the water collects. The new plan consists in dividing the field into different sections, separated by suitable dams, and arranged so that the drained water collects at one end of these fields; the slants given in each case are reversed diagonally. The drainage pipes have also reversed directions, in order to force the water to flow over the greatest possible distance, and thus make use of the total filtering surface of the field. The drain pipes are arranged at a uniform height. All the fields, with the exception of the first, have, at a certain distance beneath the surface of the soil, distributing pipes for water which is to be filtered several times. The first field is placed under water. The water collected by the drains of this section fills the collecting well up to the level of the distributing pipes of the second field and spreads in the strata through which it passes, finally reaching the drains of the second collector, which is filled up to the level of the drains of the third field, etc. These drains may all be made to communicate with one another by a series of valves arranged in the wells.

Hönig[1] declares that in the decanting basins there is not produced the slightest chemical epuration, but, on the contrary, the percentage of dissolved substances frequently increases. The epuration is mainly mechanical, but, nevertheless, the decanting under all circumstances must be effected with care, so as to obviate any possible clogging of the drainage medium. The epuration commences only after the water has passed through the first drainage field, when nitric organic substances will decompose. This same decomposition will continue and be complete when passing through the second drainage field. Then 70 per cent of the nitric organic substances are decomposed, and the resulting ammonia disappears frequently to the extent of 90 per cent, owing to the soil's absorbing powers. The other organic substances are also decomposed, and the resulting fatty acids are submitted to decomposition. The addition of lime has for its principal object the forming of insoluble calcic compounds. Waters thus treated will undergo no putrefaction, even after being exposed to the air for a period of weeks. The alkalinity of these waters has a very important influence upon the efficacy of the process; if excessive it would prevent development of bacteria producing putrefaction. Hence it is important to use lime very sparingly. The epuration is said to reach its maximum

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[1] O. U. Z. 28, 630, 1899

when the alkalinity is the lowest. The following table shows the composition [1] of the water before and after treatment and during different stages:

COMPOSITION OF RESIDUARY WATERS AT DIFFERENT STAGES OF PURIFICATION.

Periods of observation.	Substances in suspension.			Substances in solution.							
—	Mineral.	Organic.	Nitrogen.	Mineral.	Organic.	Nitric.	Ammonia.	Lime.	Potassa.	Sulphuric.	Phosphorus.
When leaving factory..........	180.2	31.6	1.81	87.6	83.8	8.9	4.4	41.16	12.8	3.8	0.23
Leaving surface drains.........	111.0	31.3	0.61	83.5	60.4	19.0	0.3				
Purified water....	0.17	1.97	....	32.3	20.9	7.6	2.3	11.5	3.5	7.9	

These data are for 100,000 parts of water. An examination of the table shows that the sulphuric acid percentage has increased This is explained by the oxidation of sulphurous compounds. Waters that have undergone drainage epuration, when repeatedly taken from the sugar factory, are finally excessively charged with mineral substances, notwithstanding the fact that the soil holds back a considerable portion of the same. Under these conditions they can no longer be used.

Efforts have been made to substitute for the draining lands artificial beds made up of various substances. GRASSBERGER [2] and HAMBURG have conducted a series of investigations to determine whether a bed of coke could be used to purify residuary water. In some of these experiments a fair degree of epuration was obtained; on the other hand, in many cases the results were not encouraging, and the water contained, besides sugar that had not been destroyed, considerable quantities of sulphuretted hydrogen. The degree of epuration obtainable depends upon the nature of the water to be epurated, and the condition of the bed of coke, which generally becomes clogged after a time. These experts claim that only the sweet water from diffusion battery and cossette presses should be epurated by these biological methods, and that there can be no possible objection to allowing the dirty water from the beet washers and flumes, after a reasonable settling, to run into the river

[1] S. B., April, 1898. [2] Oe.-U. Z., 32, 505, 1903.

By the recent PFEIFFER[1] method of epuration the residuary waters are subdivided, those from the beet washer, diffusion batteries, and the cossette presses being run into special tanks filled with coke and ashes, and having a capacity of 20 cubic meters. These tanks are filled twice a day. The water of filtration is run into iron tanks of two cubic meters capacity and filled with layers of 3 to 10 meters of coke. These waters oxidize and lose the greater portion of their organic substances; they also lose their odor of putrefaction, and no longer throw off sulphuretted hydrogen. When diluted with five times their volume of pure water they no longer are injurious to fish. A portion of these residuary waters is returned to the washer, or to the hydraulic beet carriers, only a part of the total residuary water from a beet-sugar factory being actually submitted to epuration.

There has been considerable discussion as to what micro-organisms would permit of the epuration of residuary waters. Some contend that they are the aerobes, and recommend that all the phenomena of epuration be accomplished in the presence of air; on the other hand, many authorities insist that they are anærobes, and that air should be excluded. PIEPER[2] claims that the reason the epurating of residuary water by means of micro-organisms is so slow is, that they do not find in the pores of the filtering medium sufficient oxygen to properly exert their function, and recommends mixing oxids with the water to be epurated, such as bi-oxid of manganese, to supply the oxygen needed. The nitrification of the nitric substances and the oxidation of other organic elements would then be more rapid.

On the other hand, in the filter plant of the city of Berlin, [3] the water passes through a metallic cloth upon which is placed a layer of peat and earth, intended to keep out air and light, so that the emanations may not escape. In these tanks the water undergoes a fermentation caused by certain anærobes that are active only when light and air are absent. The liquid becomes covered with a layer of scum, which, after reaching a certain thickness, remains stationary, so that it is unnecessary to remove it. From the fermenting tank the water is received in a receptacle holding.sand in layers through which it percolates from step to step, while the air circulates in the opposite direction and accomplishes a thorough aeration. The water is then received in a filter two meters deep, in which

[1] Z., 51, 1014, 1901. [2] Z. 51, 308, 1901. [3] C. 6, 934, 1898.

there are alternate layers of gravel and coke powder. The water remains in these filters from 4 to 6 hours, and is then allowed to flow into the river. The filtering receptacles must themselves undergo an aeration for 16 hours. This process is recommended for beet-sugar factories.

PART IX.

STEAM ECONOMY.

CHAPTER I.

BOILERS.

General considerations.—It is not possible to go into all the details of the technical question of general boiler management, but those pertaining to beet-sugar factories only are of primary importance. In a beet-sugar factory the steam consumption is extremely variable, as the demands upon the motive force increase and diminish from hour to hour. The exhaust-steam production and its utilization also vary within wide limits with the beginning or completion of a strike in vacuum pan. The conditions, consequently, are such that a special type of boiler is needed in order to keep the pressure constant. The steam should be rapidly generated and constitute, as it were, a sort of pressure regulator. The special boilers for beet-sugar factories should hold a large volume of water, and the vapor chamber above the surface of the water should not only be very large, but should be high enough to prevent all possible chance of entraînement when the steam consumption increases suddenly.

There are numerous advantages in having the steam at the highest possible pressure in the engines furnishing power for a beet-sugar factory. On the other hand, high pressure for the multiple effect, etc., is not of the same importance, for the simple reason that steam at high pressure does not yield a much greater number of calories than steam at low pressure. The argument does not hold good when the actual mechanical power is needed, as the

power created is proportionate to the pressure furnished. Experience shows that a pressure of 6 atmosphere gives satisfactory results. For the various heating operations, steam at low pressure can be used.

Divided batteries of boilers.—The exhaust steam from the engines is collected in a special receptacle, but it frequently happens that this supply is not sufficient to meet the demands, and, in that case, instead of drawing upon the steam from the high-pressure boilers, some experts find it advantageous to have other boilers at a lower pressure to supply the heat wanted. CLAASSEN approves this idea, when the boilers are divided in this manner as the result of circumstances, and when it is not especially prearranged, when, for example, new high-pressure boilers are installed, and when the old ones, working at lower pressure, are still to be run in order to meet the steam consumption of the factory. According to this same authority, it is a mistake to install in a new plant two kinds of boilers for the two different purposes. With a known quantity of coal, it is possible, under such circumstances, to produce nearly as much steam at 6 atmospheres as at 3 atmospheres. Notwithstanding the fact that in the first instance the difference in temperature, between the gases during the heating and the water in the boiler, is less by 20° C. than in the second case, the heat transmission does not decrease actually as the coefficient of heat transmission increases with high temperatures. The losses of heat through the evacuated gases are about the same in each case. Furthermore, by transforming steam at 6 atmospheres to a pressure of 2 to 3 atmospheres by running it through a valve, no heat is lost. Consequently, no actual advantage is obtained by dividing the boilers into two series.

SCHMIDT[1] agrees with CLAASSEN that there cannot be a great difference in the efficiency of a high- and low-pressure boiler, for the reason that the difference of heat needed to raise the steam at different pressures, as 1.7 atmospheres and 6.8 atmospheres, is less 2 per cent. At these same pressures there is a variation in temperatures of 40° C. Supposing that between gas and water this difference of temperature is 350° C., that would be only $\frac{40\times100}{350}$, or 11.4 per cent. Furthermore, one must make allowance for the decreased coefficient of transmission with the temperature. The

[1] S. I., 55, 586, 1900.

layer of soot increases with the decrease in temperature of the surface with which it comes in contact, and when working under low pressure it frequently follows that the temperature of the gases in the flues is higher than it is in high-pressure boilers.

A practical experiment made by SCHMIDT,[1] at 5.16 kilos and at 1.97 kilos pressure per sq. cm., gave a steam production of 5.92 kilos at high pressure and 5.95 kilos at low pressure, showing that there is practically no difference. He[2] concludes that there is no advantage, either from a practical or a theoretical standpoint, in working under low pressure. This same authority,[3] however, points out that when the boiler battery is working in two sections the work is simpler and more rapid, and so the fuel consumption is indirectly decreased, resulting in considerable coal saving. There results an economy, not from a higher efficiency of the boilers, or an easier production of steam, but from a reduction in the quantity of steam used in the factory. One must take into consideration the greater cost of the plant for two systems of boilers instead of one. There is more piping, and consequently a greater loss through radiation.

COLLIGNON[4] examines the issue from an entirely different standpoint. If there is only a single-boiler battery, the pressure in the boilers is lessened when the graining in the vacuum pan begins; and at once less mechanical power is obtained from the steam engines, which necessarily causes a decreased efficiency of all the appliances depending on them. In order that this pressure shall again become normal, more coal must be piled on the grates, which is certainly not economical. On the other hand, when there are two-boiler batteries the machines work with mathematical regularity, for the reason that their consumption of power undergoes very little variation. As regards the vapor utilization for heating throughout the factory, the pressure is of no importance, for the number of calories remains about the same. COLLIGNON supposes that in the low-pressure boiler there may be variations from 3 to 6 atmospheres. Evidently, the extreme limit must be the exception, otherwise there would be no economy in this method. Efforts should be made to obtain an average, and, when the extra demands for steam are made, the pressure will not fall too low. It may happen that there are two pans, the one beginning and the other

[1] S. I., 55, 591, 1900.
[2] S. I., 55, 628, 1900.
[3] S. I., 55, 649, 1900.
[4] Bull. Asso., 20, 303, 1902.

finishing its graining. At that instant the steam must be at a comparatively high pressure, and one would have to draw upon the high-pressure boiler, which would result in numerous complications. The pan man is then able to use, at his option, steam at low or high pressure, and he generally selects the latter.

VRANCKEN points out that it is possible to obtain nearly a constant pressure with one boiler battery of large size, provided it is closely watched and has the requisite heating surface. Heating with live steam is being less and less used, and the multiple-reheating method is taking its place.

Superheated steam.—According to CLAASSEN, the use of superheated steam for the working of the engines, which in some industries has proved a success, offers no advantages in a beet-sugar factory. When the ordinary temperature of the gases of combustion in the flue is from 250° to 300° C., they cannot be utilized for the superheating of the steam, for the reason that the small difference of temperature between them and steam would demand large heating surfaces and an expensive plant in order to produce the requisite superheating of about 200°. It is not advantageous to use directly heated superheaters, for the reason that the caloric power of the fuel is better utilized in the steam boilers, where the heat is transmitted to a liquid.

CLAASSEN[1] declares also that superheated steam cannot be used to reheat, evaporate, and to grain beet juices. Superheated steam plays the part of an inert gas, and will not condense on the heated surfaces before its temperature has fallen to the point at which it becomes saturated steam, and until that moment is reached very little heat is given off. A superheating, even of one degree centigrade, has a perceptible destructive effect. The economy of superheated steam in the pipes does not exist, and the heat losses by radiation will be as heavy as if saturated steam had been used. In theory it would be desirable to have steam exactly saturated, but this cannot be realized in practice. According to this, it is also impossible to reach this point by mixing superheated steam with moist or damp steam, as a comparatively long interval of time is required before the superheated steam can evaporate the condensed water molecules carried by the moist steam. These arguments comprise the objections offered to the WEIBEL-PICCARD method, in which the vapors from an evaporating appliance are

[1] Z., 50, 807, 1900.

utilized in a superheated condition. The use of superheaters should be confined to boilers, in which the steam generated is very moist.

MARTIN[1] does not agree with CLAASSEN, and suggests that superheated steam may be used to advantage, especially where the steam pipes are exceptionally long. He recommends superheating to 330° C., this steam to enter the cylinders of the engines at 220° C. Every possible precaution should be taken not to use copper, soldered pipes, etc. Superheated steam will cool very considerably when circulating through pipes; for example, the fall of temperature may be 100° C. for an 85-meter run. It is claimed that this steam may be mixed with live steam for heating, and excellent results are said to have been thus obtained.

According to LEWANDOWSKI,[2] if one wishes to make direct use of superheated steam under the best possible conditions for the evaporation, the limit of this super-saturation should be such that the steam will not condense in the pipes connecting with the vacuum pan, and this point alone would ensure an important economy. This argument is based upon the idea that superheated steam is not suited for heating; and, pursuing the same line of argument, it is feared that the exhaust steam from engines working with superheated steam will also be superheated, and not suited to the evaporation. MALANDER claims that the exhaust steam at 0.5 atmospheres from engines working with superheated steam at 220° to 230° C., and at a pressure of 6 to 7 atmospheres, is saturated. The main objection to the use of superheated steam is, that it necessitates using special oils for lubricating purposes in the slide-valves, etc., and special packing for all joints with which the steam comes in contact, as most machinery and appliances would not stand these high temperatures. He also points out that superheated steam, even at 250° C., is perfectly suited for all evaporating and graining purposes.

Water for feeding the boilers.—Another difficulty arising in beet-sugar factories is with regard to the water for the boilers. The factory furnishes a considerable volume of water for this purpose from the multiple effect. The temperature of this condensed water depends upon the pressure at which it is produced. The hottest water comes from the fore-evaporator and the first compartment of the multiple effect, and has a temperature of 110°

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[1] D. Z. I., **27**, 650, 1902. [2] C., **10**, 910, 1902.

to 120° C. In many factories these hot waters are collected under pressure in closed reservoirs, and are separately pumped into the boilers at temperatures higher than 100° C. As these very hot waters are not sufficient to meet the demand, one is compelled to draw upon the water of condensation of the other compartments of the evaporating appliance, having temperatures of less than 100° C. These waters of varied temperatures may be collected in a common reservoir, where the ultimate average temperature will be about 100°. If the condensed water at 75° to 80° from second, third, or other compartments are only occasionally drawn upon, or are used for other purposes, the water returned to the boiler seldom has a temperature lower than 90° or 95°. The pumps used for feeding the boilers with water at this temperature work without perturbation when the suction valves are pushed open by the water, that is, when the water tank is at a higher level than the valves.

It is only in very exceptional cases that a beet-sugar factory has to feed its boilers with fresh water, as a large proportion of the steam generated in the boilers is again returned to them. The losses are comparatively slight, and arise mainly through carbonatation-froth arrestors. In years when beets contain high percentages of nitric substances, the resulting juices throw off considerable ammonia; and if the resulting ammoniacal waters were continually returned to the boilers the steam would become saturated with it, and the brass mountings of the factory would soon be eaten away. Consequently, experience shows that in such cases, in order to be on the safe side, it is better not to send to the boilers the condensed water from the second compartment of a multiple effect. In such a case considerable fresh water is needed for the boiler feeding. As a general thing, very little effort is made at epurating the fresh feed waters. When there is a deposit in the boiler the purge cock is opened and the mud, etc., is blown off with the escaping water. STUEZER[1] insists that the condensed water from the multiple effect that is obtained on Sunday, after cleaning the apparatus with hydrochloric acid, should not be returned to the boilers.

Sugar in boilers.—The sugar which is sometimes contained in the condensed water, even in extremely small amounts, affects the boilers. The damage done to boilers by sugar may be of two different kinds, either chemical or mechanical, the nature of the

[1] Z., 49, 630, 1899.

injury depending upon the quantity of sugar present. If it is introduced little by little during the water feeding, it decomposes more or less rapidly, forming acids of various kinds without any appreciable separation of the solid products of decomposition, these changes depending upon the temperature of the water in the boilers. However, if a large quantity of sugar enters the boiler it will burn on the hottest portions of the tubes with which it comes in contact, and there will be formed deposits of porous carbon, the thickness of which increases to such an extent that the iron under them becomes incandescent and blisters on the outside, owing to the inner pressure. Even when the deposit is only a few millimeters thick, the strength of the plates is affected. These difficulties evidently diminish with tubular boilers. No matter what the deposits are, they always cause a decreased efficiency of the appliance, as, when the section is reduced, the circulation is lessened, but in tubular boilers there is less danger of an accident.

This sort of boiler deterioration from the use of water containing sugar in solution is very rapid, the transformation being apparent even after a few hours if large quantities of sugar are present. The only remedy is the immediate stoppage of the entire boiler battery, or at least the use of a blow-out in the boiler containing the sugar. The higher the pressure in the boiler the greater will be the rapidity of the sugar decomposition, and for this reason the general surveillance should be more careful in high-pressure boilers than in those having a low pressure. The sugar complications in the boiler are slight when the proper precautionary measures are taken to prevent sugar losses in the multiple effect, and when the condensed water from the reheaters and that from the vacuum pan are not used for feeding the boiler. The reverse is the case when irregularities occur in the working of the evaporating apparatus or vacuum pan, whereby the vacuum disappears, or, when the pressure in the juice compartment becomes the same as in the steam chamber because of a leaky tube or a coil, the juice mixes with the condensed water with which the boiler is fed. When such irregularities exist, the sugar percentage of the water should be determined, first by the taste and then by regular laboratory examinations; and when the presence of sugar is demonstrated, fresh water must be resorted to for boiler feeding. This change should be made with the least possible loss of time. In many factories no provisions are made for such an emergency, and all the connections with the boiler tank must be closed, and the tank itself emptied

through a large bottom valve before the pure fresh water is drawn into it.

The second kind of boiler deterioration caused by the sugar in the water is of a chemical nature, as the acid formed by the decomposition of sugar attacks and corrodes the iron plates. The nature and extent of this corrosion depends upon the quantity of sugar present and upon the steam pressure—that is to say, upon the temperature—and finally upon the period during which the action lasts. The higher the temperature of the water in the boilers, the greater the rapidity with which the sugar is transformed into acids. Consequently, if the pressure in the vacuum pan does not generally exceed two atmospheres, the sugar is decomposed very slowly; but in a pan where the pressure reaches 6 atmospheres (164° C.) the decomposition is rapid, and the acids formed have a pronounced and rapid corrosive action on iron at that temperature.

It is impossible to prevent small quantities of sugar from finding their way into the boilers during the manufacturing campaign. In order to prevent their destructive action, according to CLAASSEN, the water fed to boilers should be kept alkaline by the addition of soda, and this alkalinity should be regularly determined after each change of watch and for each boiler. The alkalinity should not be very high, as otherwise the water in the boiler will be frothy. The most desirable alkalinity is that corresponding to 10 cc. of tenth normal acid for 100 cc. of water in the boiler. For this test, rosolic acid may be used. If this alkalinity decreases, it shows that sugar is dissolved in the water, the quality of which may be calculated upon the basis that 0.0114 gram of sugar neutralizes 1 cc. of an alkaline tenth normal solution, or 2 kilos of sugar will saturate 1 kilo of sodic carbonate.

It is absolutely necessary to separately examine the water in each boiler, as the conditions are not the same in every case; for example, one boiler may have been fed just at the time when the water used had the greatest sugar percentage. When the steam generated has a slight odor of decomposed sugar, or when it shows signs of coloration or is frothy, the water should be tested. Unfortunately, when the odor becomes noticeable, it is too late to entirely overcome the difficulties which arise from the decomposed sugar finding its way to the machinery, where it obstructs the working of the valves, the oils no longer lubricate, and numerous other difficulties arise.

CLAASSEN says that a pronounced coloration of the water for

boilers is not objectionable, provided the water is alkaline. A slight layer of lime upon the boiler plates will offer a protection against the action of sugar; and such deposits may be said to exist in all boilers, because, when the sugar campaign commences, and also on Sundays during the cleaning of the multiple effect, the boilers are fed with ordinary water. This protective action, however, cannot be depended upon entirely, for the reason that the lime may become gradually detached from the iron. According to Claassen, the rules for preventing the destruction of boiler plates may be summarized as follows:

(1) The exclusive utilization of the condensed water from the evaporating appliances for feeding boilers, and testing this water to determine its sugar percentage, especially in cases where the vacuo is not normal in the appliances from which it has been taken.

(2) The maintenance of a specified alkalinity of the water of the boilers by the addition of soda, and the regular examination of each separate boiler.

(3) To isolate at once any boiler of the battery in which there is evidence of a pronounced acid reaction, or in which excessive frothing exists.

(4) To test at once the water of the boilers when the slightest characteristic odor of burnt sugar is perceptible, or when a pronounced dark coloration is shown in the water gauges.

(5) To feed the boilers, before the sugar campaign begins, with ordinary water that will yield a calcareous deposit, so as to obtain a thin protective layer of this substance.

(6) At the beginning of the campaign, the waters of condensation must not be utilized for boiler-feeding unless they are perfectly limpid.

When the sugar in the boilers reaches considerable proportions they are emptied one after another. The fires in each case must be successively extinguished, and all the brick work thoroughly cooled, before the water is run off. The inner cleaning will be necessary only in case the sugar issue has been too long neglected. If the arrangement of the boilers does not permit of their entire emptying, the water is simply allowed to gradually escape, replacing it by fresh water, without making any important change in the inside pressure. When all the sugar has been eliminated the work goes on as usual.

Fatty and oily substances in boilers.—Waters of condensation, obtained by the condensation of exhaust steam from the machines,

generally contain lubricating oil. As oils or fatty vegetable or animal substances decompose in the hot water of the boilers into free fatty acids which attack iron, the use of such oils should be excluded. The cylinders of the pistons should be lubricated with mineral oils, some of which consist of pure hydro-carbons, and cannot give rise to the formation of acids. They have, however, an objectionable action upon boiler plates when present in large quantities, as they may form viscous flakes with the deposits which all waters contain. These flakes deposit upon the tubes, and thus decrease their power of heat transmission to such an extent that the water will not prevent the tubes from becoming red-hot. One may, in a measure, overcome these difficulties by using large reservoirs, with a suitable overflow, as waiting tanks. The oil that is finely distributed in the water has time to rise to the surface, and may be eliminated by the surface flow.

It has been suggested, on account of the grease contained in them, that the condensed waters from multiple effects be filtered through some substance before being fed to the boilers; but this plan has been introduced into comparatively few beet-sugar factories, as the expected results were not obtained. The only practical method is to insist that the lubrication shall be more carefully conducted. The oily flakes before mentioned are objectionable from another point of view, as, before being deposited, they float either upon the surface or in the water, and obstruct the water gauges, stop cocks, etc. In order to overcome this difficulty, CLAASSEN has proposed to place in the boiler, and on the bottom of the boiler plate, a piece of sheet-iron, bent so that it will be in a vertical position before the tubes of the water gauges, with its lower portion reaching the fire tube and its top nearly touching the upper surface of the boiler. Under these conditions there will be a space, in part of the tubes, in which the water will be comparatively at rest, and the mud that penetrated beneath will be again deposited at the bottom, while the oily combination cannot reach the upper portion, even when the contents of the boiler are in a frothy condition.

Heat economizers.—In most industries, efforts have been made to utilize in one form or another the heat lost in the flues, but comparatively little has been done in beet-sugar factories in this direction. The appliances used are termed economizers. Before the hot gases are allowed to escape into the chimney, they are made to circulate between the tubes of the reheaters. This does not

mean a considerable economy of steam, because the feed water in the sugar factories is already heated almost to the boiling point. The best method for heat-saving, and consequently the ultimate economy of fuel, is to have all piping through which the steam circulates well covered with some insulator or calorifuge, and to have a rational plan of steam utilization.

CHAPTER II.

STEAM ENGINES AND CENTRALIZATION OF MOTIVE POWER.

Expansion or full admission.—What constitutes the best steam engine for a beet-sugar factory is by no means a settled question. Some authorities claim that the engine should be of the most improved type; but there are many arguments to show that very simple engines, such as have been in vogue for a long time, answer the purpose.

The amount of heat required for the production of exterior work —not only that which is needed for actual work, but what is necessary to overcome also the resistance due to friction—should be calculated upon the basis of the caloric laws. CLAASSEN offers some interesting arguments upon this question. He says that, for the production of one horse-power in the cylinders, about 1.18 kilos of steam are condensed per hour. Besides this outside work, the steam must accomplish an amount of work, the outcome of expansion, which varies greatly with different machines. In the low-admission machines, the work resulting from expansion is produced only on the side of the exhaust of the steam cylinders, while, in the expansion machines, it occurs simultaneously on both sides of the piston. Consequently the percentage of heat losses is considerably greater in the improved expansion engines than it is in full-admission engines; on the other hand, for the same exterior work, the losses are evidently less, for the reason that the total steam consumption is less. CLAASSEN points out that the heat losses during the working of 100 kilos of beets, expressed in kilos of steam, may be calculated as follows:

	Kilos.
Through cooling in the pipes................	2.1
Through cooling in steam cylinders...........	1.5
Through the production of work on the engines	1.2
Through the expansion of steam.............	1.5
Total loss..................	5.3

This loss represents about 15 per cent of the steam used by the machines, and is only 0.5 kilos more than it would have been with improved types of expansion engines. These losses were formerly considered to be much higher. JELINEK claimed that, with the old types of steam engines, as much as 30 per cent of the weight of steam introduced into the cylinders could condense during the work of expansion. The experiments of ERNOTTE [1] seem to show that the losses of heat caused by the passage of steam from the pressure of 4.5 atmospheres to one atmosphere is 6.8 per cent. This loss is directly proportionate to the extent of the expansion —it would be 9.4 per cent if the steam were to expand from 5 atmospheres to 0.5 atmospheres.

In the experiments of HIRN [2] on the condensation of steam through the interior working of expansion, a closed cylinder is used, having glass at either end and two cocks, one for the introduction of steam and the other communicating with the exterior air. If both cocks are opened it is found, by watching the conditions through the glasses, that the steam is perfectly transparent and may be compared to gas. If the two cocks are closed, the conditions remain unchanged; but if the exit cock is opened, a cloudy aspect will immediately develop, which is apparently the result of heat absorption—the necessary result of the expansion. This same authority maintains that when dry steam passes from one receptacle to another where it has less tension, and where the circulation is accomplished without doing any work, there follows a superheating which increases with the difference of tension. VRANCKEN [3] points out that according to this law the exhaust from steam engines with full admission should become superheated, and, if this is not noticeable, it is because the steam contains small quantities of water that must be evaporated before there can be any superheating. When the receptacle is in communication with the atmosphere, there is produced an exterior compression of the air, necessarily followed by a rise in temperature of the air that has been compressed and a loss of heat in the expanded steam.

When the exhaust steam of an engine forces back the steam filling the exhaust pipe and the exhaust collector, the heat lost by the expansion of the first is taken up by the second, owing to

[1] ERNOTTE, Combustible, 48, 1899.

[2] CAMBIER, Combustible, 7, 1892.

[3] La S. B., 31, 479, 1903.

the effects of the compression to which it has been submitted. It is concluded that there are no heat losses. It is claimed that in sugar factories no caloric is lost through expansion of steam, and that the only heat losses are those necessary for the accomplishment of mechanical work and those due to radiation. Instead of a condensation of 2.5 kilos of steam per sq. m. and per hour, as given by CLAASSEN, VRANCKEN[1] maintains that the steam losses are 4.3 per cent, the losses through radiation being 3.7 per cent, and that the exhaust steam from the engines gives for evaporating purposes 90 per cent of the steam furnished to them. This same authority argues that the expansion at the beginning of the admission does not mean the slightest heat loss, for the reason that the work of the expansion performed by a portion of this steam is compensated for by an equivalent work of compression on the other side.

CLAASSEN says that the substitution of the modern expansion machines for the ordinary full-admission engines is never profitable for the beet-sugar manufacturer, for the reason that the economy of steam thus obtained represents only a few hundred dollars, while the purchase of the engines in question requires a considerable outlay. Important advantages are, however, realized when one large engine is substituted for many small ones, as there is then not only a saving of steam for the machines, but at the same time there is a decrease in the heat losses in the piping, which is very simple in construction and is shorter. VRANCKEN and numerous other authorities agree that the steam engines used should be most simple and need very little care; in other words, preference should be given to full-admission slide-valve engines. The most improved type of modern steam engine will economize only few calories as compared with the simpler apparatus, which, when all calculations are made, is the equivalent per diem of 100 kilos of coal for a 325-ton slicing plant. It is important that the exhaust steam obtained should not be in excess of what is needed, and that it should not be allowed to escape freely into the air, a clear loss involving a waste of coal that amounts to quite a sum during a hundred-day campaign. For these reasons, old engines working with regularity should be replaced by new ones only in cases where the exhaust from the machines is in excess and cannot be entirely utilized during the evaporation of the juices, etc.

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[1] La S. B., 31, 482, 1903.

Vrancken recommends that, in order to obtain just the amount of exhaust steam needed, the most simple expansion engine be used, such as the Meyer type, regulated by hand, and arranged so as to allow a three-tenths admission. By changing this admission with the variating pressure in the boilers, this machine may be made to work with great regularity. First of all, one should endeavor to reduce the steam consumption by giving to the ordinary steam engine the same care and attention as is given to the more perfect machine. The seats of the slide-valves should be wel planed, the slide-valve itself should be exactly adjusted, the packing of the pistons made perfectly tight, and the engines regularly tested with the indicator. It is evident that the use of expansion and compound engines with a condenser is not at all advisable in beet-sugar factories, and may actually be considered as a wasteful arrangement, for the reason that in such machines the heat of the exhaust steam cannot be utilized for evaporation, and, such being the case, the heat losses are greater than they are with the old types of steam engines.

Centralization of motive power.—There are comparatively few beet-sugar plants that have exactly the kind of engine needed. the theories on the subject, as shown in the foregoing, being very contradictory. Cambier suggested that the heat losses might be overcome to a great extent by the use of one central steam engine giving all the power needed for the shafts, pulleys, belts, etc., of the factory. But practical experiments that have since been made do not encourage the adoption of this plan, as numerous complications result. Many of the machines of a sugar factory work irregularly, and for them all to depend upon a central one does not meet the requirements. For example, in the lime kilns the activity of the gas pump depends upon the activity of the kiln, the filtering efficiency of a filter press, and the workings of the scum pumps vary also to a considerable extent. In the modern installations, centralization of the machines is always introduced to some extent. However, a single central engine, upon which all the motive power and pumps of the factory depend, should not be used. The introduction of the suitable transmission shafting, etc., necessitates a considerably greater money outlay than when several machines are used to accomplish the same purpose.

Claassen also makes the point that the general security of the work is greater with several machines than with one upon which everything depends. From many points of view, exception might

be taken to this assertion. Without doubt, the essential condition for the successful running of a beet-sugar factory is regular working. Each perturbation means considerable loss due to increased cost of manufacture, the prolongation of the campaign, and the resulting sugar losses. A beet-sugar factory with less modern steam engines, which work without perturbation and with proper utilization of the exhaust steam and apparatus, will always yield better results than one having steam engines with all the modern appliances, when these do not permit, owing to certain irregularities that may occur, the entire utilization of their productivity.

Experience in several factories coming under the writer's notice points to the fact that frequent mistakes are made in estimating the economy of the central-engine arrangement. It means a greater money outlay than is generally supposed. It should always be remembered that the transformation in the general arrangement of a factory necessitates altering other installations, if the advantages offered by the new apparatus are to be fully utilized. For example, the centralization of the engine installation generally demands a new arrangement of the boiler battery; it involves a reduction in the volume of the exhaust, and a corresponding transformation in the evaporation. All these details increase considerably the cost of such changes.

Electrical power.—The centralization of power has made great progress since the electrical transmission of power has become practicable. Numerous complications arising from long shafting, etc., have been largely eliminated, and, furthermore, the plans of the factory may be changed at far less cost than in the case of the centralization of an engine. Certain French factories visited by the writer, such as ESCAUDOEUVRES and MEAUX, have introduced these electrical innovations. Among the most important applications of electricity in sugar factories may be mentioned the working of pumps, lifts, lime crushers, crystallizators in motion, and, more recently, centrifugals. Under another caption, mention was made of the possibility of recuperating by polyphased currents a portion of the inertia incurred in the use of brakes when the motion is received through belting and pulleys.

For many years it was claimed that the transmission from a distance always involved a considerable loss of power, absorbed in different ways. TOURNEUR,[1] discussing transmission by belting, says that it always causes a loss of 20 per cent, and that as a gen-

[1] Bull. Synd., 25, 735, 1897.

eral rule a loss of from 30 to 40 per cent of the total power given results. On the other hand, through the use of improved high-tension engines, great perfection has been attained through electricity. Brunswick's data on the subject are as follows:

For 10 kilowats (13.5 HP.) the efficiency is 70 to 80 per cent.
For 30 kilowats (40 HP.) the efficiency is 87 to 89 per cent.
For 50 kilowats (65 HP.) the efficiency is 90 per cent.
For 100 kilowats (135 HP.) the efficiency is 91 to 93 per cent.

Furthermore, with electrical transmission of power, the arrangements of the steam engine may be much simplified. At the Meaux factory, Laval turbine wheels are used, and in a very small space an enormous power may be obtained. An electrical installation permits of numerous alterations at very little expense, and is easily operated.

Low-temperature engines.—Of late it has been proposed to utilize more of the waste heat from the numerous stations of the factory. It must be noted that most of this lost heat is at a too low temperature to produce steam at sufficient pressure for the engines. On the other hand, other liquids with lower boiling temperatures can be brought to a high pressure by this lost heat, and can transform this caloric energy into dynamic energy. It has been suggested that ether or sulphurous acid be used for this purpose, and that liquid anhydrous sulphurous acid be vaporized in a special tubular boiler through which circulate the vapors from the last compartment of a multiple effect; an air pump draws off the air and condensed water. The sulphurous vapors produced by watery vapor at 60° C. would have a pressure of 9 to 10 atmospheres, and with the vapors from the vacuum pan a pressure of 18 atmospheres could be obtained. The condensation of the sulphurous acid offers no difficulty. The motor to be used is made of bronze, or of a special iron which is not attacked by the chemical so long as it is not combined with air. The general shape is that of an ordinary steam engine, but with very wide admission parts. The piston rod alone needs lubricating, as the anhydrous sulphurous acid does its own lubricating in the cylinder. Steffen[1] claims that such motors will not result in the economy expected. On the other hand, he favors an extended trial of the plan on a large scale in sugar refineries working the entire year. It would not be surprising if in a few years these low-temperature motors should find a very general application in beet-sugar factories.

[1] C., 11, 909, 1903.

CHAPTER III.

HEAT LOSSES.

Sources of losses.—Besides the economy that may be effected in boilers and engines, there are numerous other centres in the factory where an important saving is possible. Common sense should be used in regard to the employment of the exhaust steam in the multiple effect and in reheaters. The question of loss of caloric from coal long exposed to the open air was doubted, but the fact is now proven beyond cavil. Hence it is not desirable to allow it to accumulate in the yards of the sugar factory if it is to remain there for a period of months. FAYOL has proved that the phenomenon in question arises from an oxidation of the carbon. MAHLER [1] is of the same opinion, and demonstrates that the calorific power may be diminished by 20 per cent during long exposure. Experiments seem to show that this loss is greatest with soft coal, as the anthracite coal does not undergo these changes to the same degree.

One of the most important sources of heat loss in the factory is radiation. The extent of these heat losses from cooling in the pipes depends upon many circumstances, but mainly upon the length of the pipes, the kind of isolating calorifuge used, and the difference of temperature between the steam and the exterior air. The reduction and simplification of the steam piping and covering the pipes with non-conducting material will contribute towards decreasing the heat losses. The high-pressure pipes will throw off more heat than those of low pressure, as, for example, the pipes connecting with the exhaust. In the cylinders of the steam engine, which cannot be covered, there are greater losses per unit of surface through cooling than occur in the piping. However, as their total area is not very great, these losses alone cannot be very extensive.

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[1] ERNOTTE, Combustible, 12, 1899.

The leading authorities do not agree as to the amount of the losses through radiation. Some claim 2.5 and others 5 kilos of steam per hour and per square meter of the exposed metallic surface. The steam pressure has much to do with these variations, also the ambient temperature and the thickness of the metal. The experiments of PASQUE[1] show that for steam saturated at 100° C., or 172° C., also for superheated steam at 250° C., the respective losses are 673 : 1612 : 330. CERNY and HAUNER[2] have calculated the total heat lost through radiation in a 235-ton plant as amounting to an equivalent of 4.5 tons of coal, or 2 per cent of coal, not including the losses through the piping. This could be reduced by one-half through the use of some isolating substance. The experiments on the same lines by POKORNY are equally interesting. The calculations into which he enters are very intricate, and include the losses through radiation in the pipes, etc. He concludes that this total is 17.67 kilos of steam per 100 kilos of beets sliced. If it is supposed that 7 kilos of water are evaporated per kilo of coal, this means a loss of 2.5 per cent fuel.

POKORNY mentions a number of ways of reducing these losses. Most of them are known, but are given concisely. All steam pipes should be as short as possible; apparatus should be single, and not double, when such is possible, as there is then less radiating surface; the diameter of the piping should be within a fraction of what is needed, so as to prevent unnecessary losses. Not only the steam pipes, but also those for the juice and hot-water pipes should be protected by a calorifuge—not a cheap isolator, but the very best product the market can supply. Neither the steam nor the juice should ever be at a higher temperature than is absolutely necessary, for the reason that the losses through radiation are then proportionately increased.

If the condensed-water purgers get out of order a considerable heat loss results. It is very difficult to prevent leaks in these valves, and necessarily both the hot water in question and also steam escape into the air. This difficulty is not readily overcome, and when it is discovered the purger should be unmounted and repaired.

Carbonatation is also responsible for important heat losses. The caloric removed by the lime-kiln gases is inversely proportional to their temperature; that is to say, the hotter the juice, and the

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[1] B. Z., 22, 5, 429, 541, 634, 695, and 753, 1897–98.
[2] B. Z., 12, 250, 1888.

cooler the carbonic-acid gas, the greater will be the heat carried off. When conducting this operation at a lower temperature, the difficulty may, in a measure, be overcome. It remains always to be decided from a practical standpoint just within what limits this idea may be applied. The steam-froth arrestors are frequently abused. If the perforations of the steam distributors are too large, there will be a useless expenditure of steam, and consequently of heat. It is during the diffusion that the heat losses are the greatest; for the residuary water from the cossettes is frequently at a temperature higher than 40° C., and one may imagine how much caloric this vast volume of residuary product must retain. If it is to be handled in a Buettner and Meyer dryer, the heat stored up in the exhausted slices is a gain for that operation, and the actual loss is consequently reduced. Upon general principles, it may be said that the water used in a diffusion battery should be heated with steam that would otherwise be wasted. In certain factories visited, the diffusor is washed with cold water, and so much caloric is thus economized.

Fuel consumption.—One of the most important problems in beet-sugar manufacture is how to save coal. As has been shown in the foregoing, attention given here and there means an important saving when the whole campaign is considered. Just how much coal should be used cannot be stated, as it depends upon so many factors, such as the saccharine quality of the beets, the process of manufacture, local conditions, kind of fuel used, etc. One fact is certain,—by comparing the averages from year to year, it is shown that the coal per 100 kilos of beets worked has considerably decreased. Twenty years ago, some plants in France consumed 500 per cent of the weight of refined sugar made, and an average of 250 per cent was considered most satisfactory. Now this average has fallen to 114 per cent.

When one compares the data furnished by French official statistics,[1] it is shown that, owing to the gradual disappearance of the poorly maintained and smaller factories, the coal consumption during the campaign 1889–90 was only 20 per cent of the weight of the beets sliced, while in 1901–02 it fell to 12.8 per cent. Unfortunately, these figures cannot be compared with those of Germany, —for example, where the fuel consists of most varied substances, such as peat, lignite, etc.,—and therefore it is better to base the com-

[1] Liste Générale, 35, 202, 1904.

parison upon the steam consumption. CLAASSEN estimates that, when a beet-sugar factory uses in steam 57.4 to 62.6 per cent of the weight of beets sliced, it is working under excellent conditions. If this be reduced to coal, admitting that a first-class modern boiler is used, it equals 7 kilos of coal per 100 kilos of beets, or 70 kilos per ton. This limit is very difficult to reach. The calculations of HORSIN-DEON[1] with a quadruple effect give 90 kilos. It is supposed, however, that there is considerable drawing-off from the diffusors. ABRAHAM[2] maintains that, through the use of the GREINER-PAULY apparatus, the coal consumption may be reduced to 75 kilos.

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[1] HORSIN-DÉON, Traité, II, 2, 887, 1900.
[2] ABRAHAM, Dampfwirtschaft, 117, 1904.

PART X.

PRACTICAL WORK OF A BEET-SUGAR FACTORY.

CHAPTER I.

HINTS RESPECTING GENERAL MANAGEMENT.

Personnel.—A beet-sugar plant of the most recent design and satisfactory beets are not the only conditions necessary for the profitable manufacture of beet sugar; certain practical essentials must be assured. There must be one head to the entire organization, and from him should come the orders, thus avoiding confusion either in the practical or technical working. Unfortunately, there is always a certain rivalry between the chemist of the laboratory and the overseer who has charge of the various stations of sugar extraction. Experience shows that, when the chemical examinations reveal faulty methods of working, the changes to be made should not be ordered directly by the chemist, but through the overseer, whose duty is not to make regular rounds at given hours, but to move about the factory. This keeps all stations constantly on the alert, and in the intervals special attention may be given to some station that is not up to the standard. It is generally during the night that there is neglect at some station of the juice, syrup, etc., manipulation. During the cold winter, the tendency of the hands is to find some warm spot, such as in the boiler room, near the lime kiln, etc. Whenever there is a change of watch, the new gang should find all in a perfect condition of cleanliness, and not be obliged to gather up the dirt left by their predecessors on operations only half completed. It is often found advantageous to offer premiums, arranging it so that all hands are interested.

No station of the factory demands greater activity than the diffusion battery; the higher its efficiency the greater will be the ultimate quantity of sugar extracted. The battery man should be young, and rapid in his movements in the handling of the numerous valves at the right moment as any inattention or slowness would cause a considerable loss. The battery man should have three assistants, one to close the upper cover, another to force the cossettes to pack well into the diffusor as they fall from the distributing hopper, and one underneath the diffusor to watch the opening and closing of the bottom door. The slicer man should be in constant touch with the assistant who has charge of the filling, so as to signal at just the right moment that the diffusor is full and no more beet slices can be added. This signalling should be carried one step further: if the slicer is full of beets, the person in charge of the hydraulic carrier should be informed, so that the delivery to the slicer may be lessened.

For a beet-sugar plant handling 400 tons of beets per diem, not less than 40 men per shift are necessary inside of the factory; in the yards, etc., at least that many more. For the first and second carbonatation, each man can handle three tanks; for the first and second filter presses, a head man, with four assistants for emptying the frames of their scums and for their handling are needed; one filter press should always be ready with fresh filtering cloths. The triple-effect man should be active, and thoroughly understand the apparatus, the construction of which varies considerably. Whereever it is possible to do so, the pan man should be changed after each strike; it is a mistake to make a change at fixed hours in advance, for each pan man should bear the responsibility for the strike he has started.

Hints respecting appliances and working methods.—It is self-evident that the cossettes upon leaving the diffusors should be thoroughly exhausted of their sugar, and the general operation of the battery should be such as to allow rapid working, providing at the same time for the necessary contact. With the circulating water, there should be a maximum sugar extraction. In order to obtain this extraction the cossettes should be very fine and regular, and this can be obtained only by well-mounted and sharpened slicing knives. The velocity of the revolving disk holding the knives has also a very important influence. The heating of the battery should not be pushed to excess, otherwise the beet slices will be cooked. If, on the other hand, the temperature in the diffusors

is not sufficiently high, the sugar will not be exhausted. In most communities 75° C. is considered a good average. The diffusor that is about to be emptied should not be heated, and from it to the head there should be a regular increase of temperature. The filling, mashing, drawing off, and emptying operations should all be performed with equal care, keeping two diffusors inactive, that is to say, with no juice circulating in them, one being filled while the other is being emptied; the latter operation should be finished before the former.

Upon general principles, it may be said that the density of the diffusion juice is 14.5° Brix at 15° C. On the other hand, with beets of high polarization this density increases, and may reach 15.5° Brix. During the entire working of the battery, samples of the exhausted cossettes should be constantly examined in the laboratory, and a careful record kept for future reference and for the technical compatibility. As regards drawing off, experience shows that the best results are obtained by keeping this volume nearly constant for each diffusor. This question is for the overseer to decide, and cannot be left entirely to the battery man, as there are many issues upon which the volume of juice depends.

The measuring tank should always have an automatic indicator, showing exactly what the volume is. The volume of juice to be drawn off may vary from 100 to 110 litres per 100 kilos of beet slices contained in the diffusor. The liming of beet juices also demands considerable attention, and should not be neglected. The quantity of lime added to the juice must be known and determined in advance. The Baumé degree of the milk of lime should be watched, and the density in question should be nearly constant. Special automatic appliances satisfactorily accomplish this work, and need very little care. The most desirable milk of lime indicates 18° Bé. Suitable tables may be used which show without calculation the amount of lime per litre; but it may be said that the milk of lime holds about as many per cent of lime as it shows degrees Bé., that is, a milk of lime at 18° Bé. holds 18 per cent of oxid of calcium. The limed juices from the waiting tanks, if from an upper elevation, enter the carbonatation tanks direct or they are pumped in. When these tanks are filled up to the gauge cock, the entrance cock and the top covering of tanks are closed, so that the resulting froth cannot run over the sides; the carbonic entrance cock is then opened. When the alkalinity reaches about 0.12 grams of lime per 100 cb. cm. the operation is completed;

during this operation, titrated paper should be constantly used, in order to ascertain whether the operation is progressing under normal conditions.

The froth forming on the surface is an excellent indication of how the operation is progressing; at first it has an abundant, thick, white appearance, then it settles and becomes gray. Samples should be taken and examined in a suitable spoon, as the aspect of the liquor gives very valuable and practical indications. There is a decided deposit, and the liquor on top is of a light-yellow hue. The generally adopted mode to-day for conducting the carbonatation is not to push the temperature beyond a certain limit, and not to boil. Frothing may be kept under control by the use of fatty substances or oil.

The overseer has to see that the carbonatation tanks are filled and emptied always in the same order. Furthermore, while in most factories two gas valves are open on the carbonatation tanks, one wide open and the other only a trifle, two or more valves should never be wide open, as it would delay the carbonatation in all tanks, and there is no advantage in having two or three tanks ready at the same moment.

By examining the scum cakes, the duration of carbonatation, the facility with which the juices are filtered, it is very easy to ascertain whether the carbonatation and the liming are made according to prevailing rules. A short duration of carbonatation indicates a shortage of lime. Too long a duration would, on the other hand, prove either that too much lime has been added, or that something is out of order in respect of the carbonic-acid gas. As to the latter, it can be that the gas is poor, and the defect will be found in the lime kiln, or the distributors are clogged, or, again, the chimney for escaping gases has become obstructed with lime-carbonate deposits.

When the filter-press scums are pasty and dark in color, too little lime has been added; when dark, but reasonably dry, the juice has been oversaturated. With normal limed and carbonatated juice the cakes are bright in color, with a little yellow hue, and present a dry aspect when they are broken. Juices handled with an excess of lime have a chalky, dry appearance. When limed, but not carbonatated, juice has been run into the presses; or, when non-carbonatated juice has been mixed with carbonatated, the scums have a chalky and pasty aspect. Such cases can readily be detected by the foam that is formed upon the juice in the exit gutter

of the filter-presses. This excess of lime can result from a false manœuvring, or from leaks in the valves of the carbonatation tanks, which should be ascertained immediately.

A great stress should be laid upon cleanliness in the filter-presses plant. The frames must be handled gently, so as not to injure the cloths. The amount of water to be used for exhaustion of the cakes should be indicated by the overseer according to the chemist's analysis of scums.

The lime kiln should be looked at repeatedly, especially in factories desugarizating their molasses by the separation method. It must be remembered that the higher the temperature in the hot zone of the kiln the greater will be the coke economy. This is, however, limited by the facts (1) that the burned lime must remain porous, (2) that it should be cold upon leaving the kiln, and (3) that the escaping gases should be at a reasonable temperature.

In factories using the PAULY-GREINER system of evaporation, the fore-evaporator should be kept under a constant pressure. In the different sections of the multiple effect, the normal conditions of vacuo should always prevail, as otherwise it would show either that a great volume of steam is escaping through the ammoniacal pipes to the condenser, or that the condensed-water pumps do not work correctly. The level of juice in the compartments should be kept constant to reach the highest efficiency of the apparatus, and the syrup should always be drawn off at the standard density.

The sulphitation and alkalinity of syrups should—just as in the first and the second carbonatation—be controlled at every instance by the overseer, or by the chemists in the presence of the man in charge. By putting one's hand on the sulphur furnace, or by opening a little cock, it is easy to find out whether the furnace is burning or not. It is advisable to verify often whether the safety valve of the sulphurous-acid pipe is not leaking. The progress of each strike should also be followed by the heads of the factory. As a rule, the superintendent, the chemists, and the overseers should understand enough about graining so as to detect any mistake during this operation. It keeps the sugar boiler on the watch. Room must always be cared for at least one or two hours before ending a strike, as sometimes the work of the pan could be checked by a massecuite slow to pass through the centrifugals.

The centrifugating must be watched more than any other stage of manufacture when the molasses are not swung out readily.

To overcome the difficulty many expedients may be resorted to, as to heat up the drum of the centrifugals, to heat the massecuite in the crystallizators, to add hot and diluted molasses, or, again, to centrifugate only half loads of massecuite, but water should only be resorted to in case of absolute necessity in an emergency. The belts should be well stretched to prevent them from falling off and to avoid the pauses in the work. The room of the centrifugals should be kept as clean as possible.

The same cleanliness should prevail in all subsequent manipulations of the sugar. The scales for weighing the bags should be cleaned as often as necessary, even several times a shift with some systems, as it is very important to have the correct figures about outgoing sugar. The bags should be of an amply good quality, to avoid losses during transportation and resulting discriminations. Mended bags should be particularly examined. Torn filter-press cloths and torn bags should not be thrown away, as they can be of use in the factory or can be sold.

A good many points are also to be controlled in the boiler room besides those mentioned in the legal prescriptions, varying in each country. Much data should be gathered there to ascertain the conditions under which the working in the boiler room and in the factory is made. Among them may be cited the weight of the coal used, the volume of water evaporated, the weight of the slags, the average pressure of steam, the percentage in carbonic acid, the temperature of the gases at their entrance in the chimney, etc. If the pressure is kept as near as possible to the limit at which the safety valves blow off, and if the grates are cleaned at regular intervals, there should be no apprehension of a sudden drop in the pressure when a new strike is started.

It is evident that too much care cannot be taken with the machinery proper, but it would lead beyond the scope of this treatise to enter into details on the subject.

CHAPTER II.

CONTROLS.

General considerations.—The control of a beet-sugar factory is much more complicated than many suppose, on account of the numerous elements that must be considered. There is the direct control by all those technically interested in the manufacturing processes, for which no special rules can be established, as the conditions of the special environment in which each appliance or phase of the operation is being conducted should be met by certain modifications. There is the chemical control, the details of which must be found in numerous special works, as, notwithstanding its importance, it is outside the scope of this treatise. There is also the control by automatic recording appliances, and, last but not the least, the bookkeeping or clerical control. When the organization has reached a certain degree of perfection, these controls should each be the sequence of the other.

Though the chemical surveillance may be considered as absolutely necessary, it must be understood that entire dependence cannot be placed upon it alone. Practical experience is an important factor in the case. The exterior appearance of the juice and the products will indicate at once the existence of some irregularity, and the difficulty may be remedied before the laboratory information is obtained.

One of the first essentials in conducting a beet-sugar factory is to cultivate a practical eye for existing conditions at any and all times during the manufacturing campaign. Any irregularity, such as neglectful defecation, carbonatation, faulty working of steam engine, and losses of exhaust, is almost immediately detected by the practical man.

Certain errors of appreciation may be made as to the manufacturing process in progress, due to some perturbation, and in this case a sample of the juice, syrup, etc., sent to the laboratory may give some indication of the cause of the difficulty; but, as a

truly average sample is not obtainable, the conclusion drawn may sometimes be misleading.

The best practical results in beet-sugar factories are reached when the superintendent of the factory and the chemist of the laboratory work together, the one helping the other, unless, which is frequently the case, the assistant superintendent is at the same time the chief chemist. Whatever be the arrangement for each special case, practical conclusions should be drawn from the chemical analysis, to overcome a difficulty when it occurs. It too frequently happens that, when the technical man is in a quandary as to the real cause of a difficulty, he will simply attribute it to the poor quality of the beets being worked, without making any effort to continue an investigation which may lead to a method for correcting some mistake, perhaps his own. There exist marked variations in the saccharine qualities of the roots from campaign to campaign, and even during the same season; but, generally, it may be said that beets that are not rotten or frozen may be handled in a sugar factory so as to give very satisfactory results. In some cases modifications have to be made in the methods of working in order to obtain the results desired. Generally, the quality of the beets is not the real cause of perturbations in the factory's running. It is usually when the campaign begins that the greatest irregularities occur; and these are not due to the non-matured beets, nor to their poor quality, but to mistakes, made by inexperienced hands, which are not immediately detected by the superintendent or the man in charge.

Controlling appliances.—The appliances used for controlling the various operations are very numerous. Many of them are entirely automatic in their working, some are only partly automatic, and others depend entirely upon the manipulation of the person in charge. The indications needed are very numerous, and if it were not for the expense entailed, it would be better if all variable elements, however small, were recorded and kept under control.

The data relating to the beets as they are received at the factory must be carefully noted. There are numerous automatic scales in use, all having certain advantages and disadvantages. In most of the factories the entire bookkeeping is based upon the weight of washed beets.

When the weighing is done on ordinary scales, the count of each weighing is kept by means of pegs placed in holes corresponding to units, tens, hundreds, etc., or upon a blackboard with chalk. This

very primitive method still prevails in many factories, and is responsible for numerous mistakes. The "Chronos," and other automatic scales, should be in more general use than they now are. The weigher should have posted up in some prominent place the total weight of beets sliced since the new watch has been on duty. Under these conditions it is possible for the overseer to know just within what limits the factory's running is up to the standard of its slicing capacity, and, if any irregularity is noticed, due precautionary measures may be taken before it is too late. An excellent method consists in keeping hourly records of all the factory's data. A large blackboard may be used for this purpose. The hour indications are shown lengthwise, while the vertical lines refer to certain data of the working. Special marks are made on the hour line to indicate the stress placed upon certain data, and these are joined hour by hour. This diagrammatic representation is readily understood by all hands, who soon grasp the significance of an upward or downward curve.

At all hours, night and day, efforts should be made to keep the factory running at its full slicing capacity. If, for one reason or another, there is a falling off, the difficulty must be overcome without delay. If the diffusion battery has come to a standstill, or the not-working diffusors are empty, then the beet slicer is not furnishing the cossettes with sufficient rapidity. If the battery's circulation is stopped, and the not-working diffusors, as well as the measuring tanks, are full, then there is some difficulty with the carbonatation, and attention should be directed to it at once. If the carbonatation tanks are empty, then the fault lies with the battery. If, on the other hand, these tanks are full of carbonatated juice, then the filter presses or pumps are not working, or possibly the second carbonatation or evaporating appliance is to blame, etc.

The automatic control of the diffusion battery is effected with the Rassmus recorder (Fig. 222). This apparatus consists of a recording cylinder which makes one revolution in twelve hours. A pulley connects by means of a string with the float on the surface of the liquid in the measuring tank. A ratch is raised or lowered by a toothed wheel on the same axis as the pulley, and a pen well fed with ink registers these motions upon a band of paper stretched on a drum and divided into hours. The apparatus has two electrical contacts which close the circuit of a bell when the measuring tank is full and when empty, so that the battery man may be kept

constantly posted. It is desirable that there should be other bells giving due warning at the same time at the other stations. The height of these contacts may be regulated, so that the drawing-off from the battery may be made to vary. The number of times the tank has been emptied is also recorded by a counting register connected with the apparatus. Instead of bells, certain plainly visible signals may be used. The Rassmus apparatus is also made with two recording cylinders, which is the type shown in Fig. 222. These are connected with two separate batteries. Any variations in the

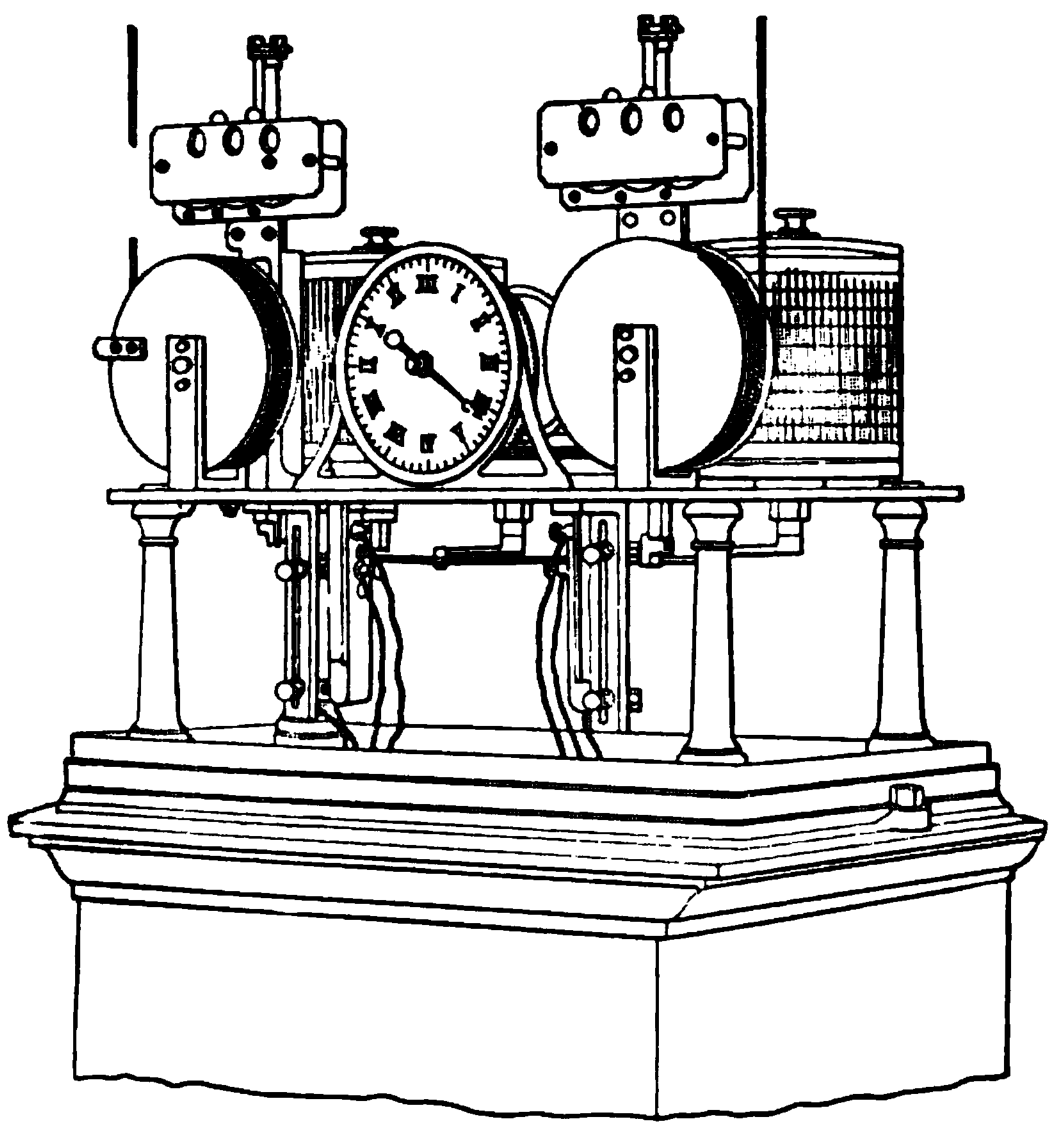

Fig. 222.—Rassmus Juice Recorder.

general work are shown on the band of paper. This appliance is much used in the beet-sugar industry, while in France the Horsin-Déon, which is the same apparatus with a few modifications, is in general favor.

The sugar percentage of the residuary cossettes from the battery may also be written upon a blackboard in some prominent position, and one would thus have within reach all the important data for the control of the diffusion. The density recorders for juices have been given a fair trial, but the indications up to date are not very reliable. For the carbonatation there is no system of control other than the standard alkalimetric tests, for which, however, efforts have been made to introduce some automatic

and systematic control. Among these may be mentioned the SCHWAGER[1] apparatus, into which the drops of liquid to be tested fall upon strips of chemically prepared paper. The changes of color at the centre of the strip indicate that the juices are standard, while those at the extremities show that the alkalinity has been exceeded, or is not up to the standard. The bands are divided so as to give hourly indications, and are rolled upon suitable cylinders. No practical application of the idea has been observed, but it is certainly worth recording.

The pressure of the vapors and the density of the juice play the leading rôles in evaporation. Pressure recorders are only placed here and there. In most factories, one upon the exhaust-steam collector and another upon the condenser are considered sufficient to furnish information as to the general working of the evaporator, but there would be advantages in having several additional ones. These appliances are so well known that they need not be described. A recording thermometer in connection with a multiple effect would also render excellent service. It consists of a metallic bulb (Fig. 223) filled with liquid, which is placed in the environment

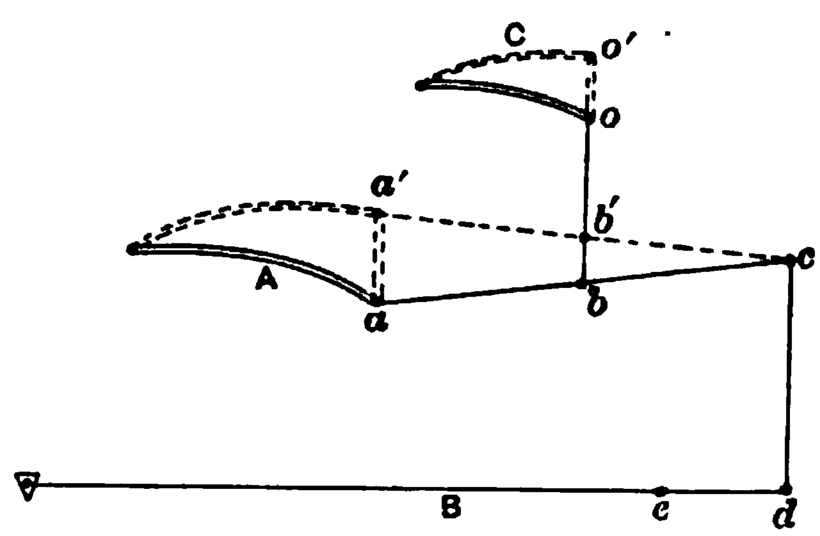

FIG. 223.—Schema of RICHARD's Compensating Temperature Recorder.

whose temperature is to be recorded, and which is in communication through a capillary tube with the hollow spring, *A*. The liquid, in expanding under the effects of heat, will bring about a deformation of the spring in question, and, that the ambient temperature shall not exert its influence, RICHARD adds a compensator, *C*. The tube, *A*, is fixed at one of its extremities, and, at the other, *a*, will influence the needle, *B*, through the lever, *a b c*, moving

[1] D. Z. I., 24, 633, 1899.

around b and the system $c\ d\ e$. The effect of the ambient temperature is corrected by the deviation of the spring, C, depending upon that temperature. The motion of C is to that of the tube, A, as aa': bb' or bc: ac. At the end of B there is a stylus that registers the temperature upon a recording cylinder covered with a divided sheet of paper. This system can be given very much the same arrangement as the dial mode of telegraphy (Fig. 224), permitting one to record at a distance any variation in temperature. The apparatus will simultaneously register the temperature in several places, supposing that there are three dial thermometers, 1, 2, and 3, placed at different stations and connected with the appliance under consideration through the so-called scrutator, shown to the left. The electro-magnet of one of these thermometers, by means of the contact, 1, 2, or 3, of the interruptor, will immediately show on the dial of the scrutator exactly what the temperature is. All the important temperatures of the factory may be recorded at the superintendent's office.

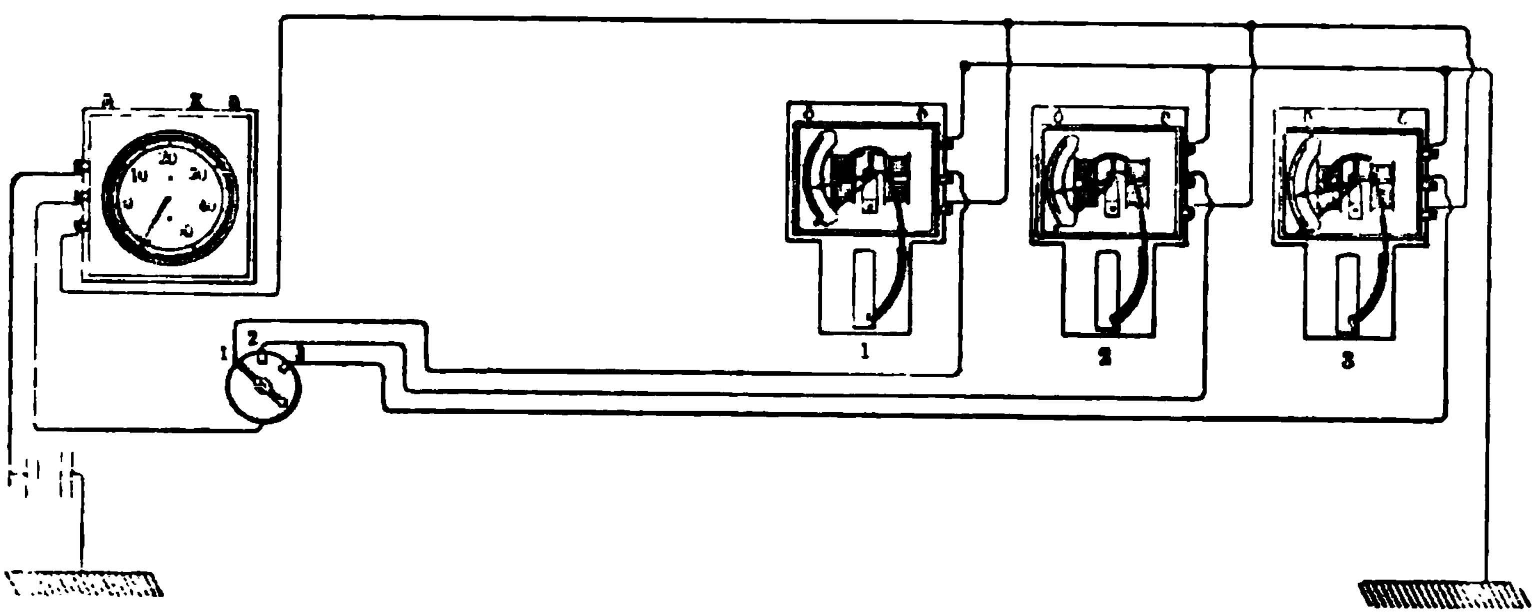

Fig. 224.—Richard's "Scrutator."

Recording thermometers and pressure gauges may also render important service to control graining. Of course they cannot prevent the appearance of false grain, but other useful information is furnished during the several phases of the pan's working. The indications necessary for this control are the vapor pressure in the heating chamber, the temperature of the massecuite, and the existing vacuum above the surface of the product being grained.

The final use of the automatic control is for the bags of sugar

leaving the factory. The device is placed below the sliding boards used for the bags. It must be very simple in its construction and prevent the registering of two bags, for example, when only one is taken from the factory or into the store.

The boiler control is too frequently neglected, and yet at that station constant watching is needed. It is most necessary to record the quantity of water evaporated, the quantity of coal consumed, the total weight of ashes obtained, and the composition of the gases in the flues. If the quantity of water evaporated is known, one may very accurately ascertain the degree of steam economy attained in the general running of the factory. This volume of water is readily determined by the use of a measuring tank, or some recording device attached to the feed pump of the boiler. It is important in this case, however, to make repeated experiments to determine its practical working efficiency. It is well to keep in mind that a certain amount of water may be carried forward through entraînement by the steam, and this may be due to several causes. It is important also to keep a careful record of the water thrown out when the boilers are cleaned. The total ash gives data as to the activity shown by the stoker, and will show whether or not considerable coal is being wasted. The most reliable control is the composition of the gases in the flues, for this gives the data by which one may ascertain whether the combustion has been complete,—in other words, whether the boiler is working under economic conditions. The richer these gases are in carbonic acid, the more complete will be the combustion.

The carbonic acid, the outcome of combustion, can be diluted only by mixing with the air that finds its way to the grate. This air is heated to the same temperature as the gases formed during the burning of fuel, and causes a loss of caloric which is in direct ratio to its volume. Such losses may represent 30 per cent of the heating value of the coal used, but by proper management this may be reduced to 10 per cent.

There exist many pieces of apparatus for the continuous control of the composition of the escaping gases. The ARNT appliance (Fig. 225) consists of a pair of very sensitive scales, loaded on one side by *b* and weights, while on the other there is a glass receptacle open at the bottom. The equilibrium is established for a known percentage of carbonic acid. The gases are slowly introduced through the pipes, *a* and *c*, into *d*, and leave through *e*. The equilibrium is destroyed in proportion to the specific weight of the gases,

provided they are always at the same temperature. The variations are shown by the scale pointer. This apparatus does not register the percentage of carbonic acid; there could, however, be attached a roller with a suitable band of paper.

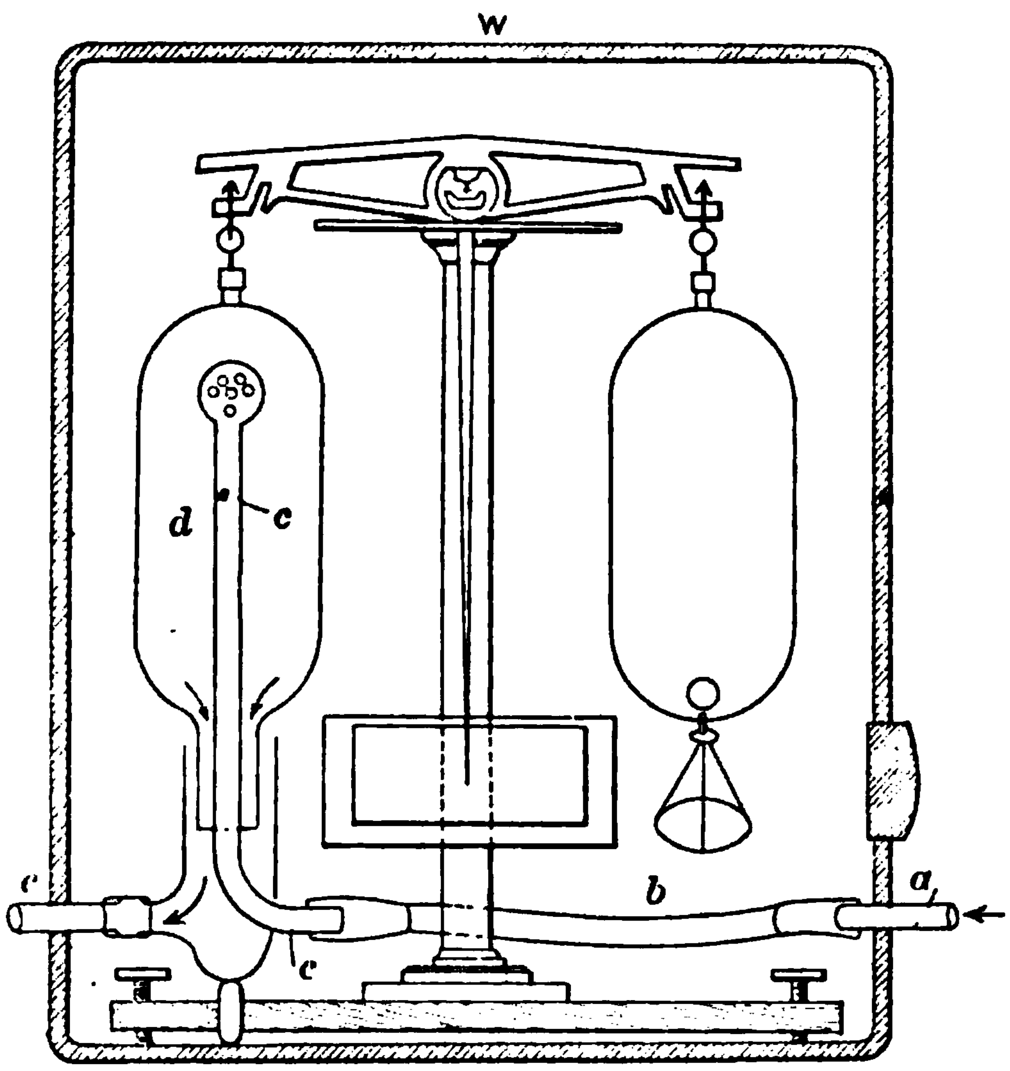

Fig. 225.—Arnt Carbonic-acid Scale.

Bookkeeping of the factory.—One of the most important features of control, considered as a whole, is the discovery of the faults, and an endeavor to overcome them at once. The difference between the quantity of sugar (polarization) existing in the beets before they are sliced and the sugar extracted is the total loss during manufacture. When the roots have been correctly weighed and their juices accurately analyzed, the total losses are frequently much higher than the sum of the losses determined by adding the sugar remaining in the residuary molasses, pulps, water, and scum. Consequently there are known and unknown losses. The known losses may be determined by analyzing the residuary cossettes, the waste water from the diffusion, the carbonatation scums, the water of the condenser, etc.

There are, however, other losses, whose determination cannot be accurately ascertained, as there are not sufficient data to work upon, and these come under the caption of Unknown Losses. Among these may be mentioned the losses resulting from sugar destruction during the evaporation or graining; the sugar losses on the filtering

cloths of the presses; and the mechanical losses through spilling, overflow, etc., of the juice or after-products. All these losses, even considered collectively, are very slight. In most cases they consist only of a few hundredths per cent as compared with the total weight of beets sliced, provided, of course, that the work is done under normal conditions, that the juice is alkaline, and that no extraordinary mechanical sugar losses occur.

Claassen maintains that unknown losses occur in all beet-sugar factories, notwithstanding all possible care devoted to the chemical and other control. On the other hand, Pellet refutes this assertion, and points out that the supposed unknown losses become smaller every year as the processes of manufacture are improved. A series of determinations [1] made in Dutch beet-sugar factories show that the unknown losses, combined with those of diffusion, were only 0.26 per cent. From the balance sheets of the factory, said by Claassen to be satisfactory, the total losses should be about 1.0 to 1.5 per cent of the weight of the beets sliced; of these, 0.5 to 0.7 per cent may be determined, and consequently nearly one-half remain unknown, and cannot be accounted for. It would be discouraging for the technical director to note enormous losses if actually considered as sugar, but they cannot be solely thus attributed, as polarization losses occur which cannot be explained.

Among the unknown losses are those of a mechanical nature, which are the outcome of leakage of the valves and heating tubes, or are due to neglect of the workman in charge. It is the duty of the practical man to prevent these losses, and even to render them impossible. During diffusion the leaky, or partly open, emptying valves may be the cause of a loss of juice, and for this reason the valves in question should be done away with in cases where the the residuum cossettes are flushed from diffusors. When the exhausted slices are flushed out from a diffusion battery that is emptied from the sides, Claassen advises to fill up and to have the space between the bottom of the diffusor and the metallic sieve as small as possible, just sufficient for the juice to circulate; otherwise a certain amount of water will remain, which, during the following washing, would tend to dilute the resulting juices. The losses resulting from leaky manholes never attain an appreciable amount, but they must not be overlooked.

Mechanical losses of juice may take place at the emptying pipes

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[1] S. B., September, 1901.

of the carbonatation tanks and of the multiple effect, these being used on Sunday for the emptying of the water used for washing. The cocks and emptying valves of these pipings should always be closed, and, as an excellent precautionary measure, be under lock and key, except when they are being used or cleaned. All the piping, for whatever purpose it may be intended, should be placed so that it is readily accessible and visible. The losses through leakage of the heating tubes and steam coils of the multiple effect and vacuum pan are at once discovered, for the reason that most of the condensed water is utilized in feeding the boilers, and the smallest possible amount of sugar would be noticeable through the characteristic odor it transmits to the steam. The condensed waters, such as those used in the reheaters, that are not fed to the boilers, should be frequently tested for sugar. It is pointed out that, if these precautionary measures are taken, no mechanical losses will remain unnoticed, and in consequence they can never become very great.

According to CLAASSEN, the losses of a beet-sugar factory are about as follows:

Total losses	1.20
The known losses are:	
	Per cent of weight of the beet.
In the pressed residuums	50% with 0.50% pol. = 0.25
Residuary sweet water from presses	40% with 0.20% pol. = 0.08
Residuary sweet water from diffusion battery	130% with 0.10% pol. = 0.13
In the residuary scums, first carbonatation	8% with 1.5% pol. = 0.12
In the residuary scums, other carbonatations	0.5% with 4.0% pol. = 0.02
In the condensed water	600% with 0.00% pol. = 0.00
Known losses	0.6

In factories where the diffusion juices are accurately measured, one may also exactly determine the total loss during diffusion, but it is necessary to have correct average samples of diffusion juices.

The question, as to whether there are produced considerable unknown losses during the working of the diffusion battery, has not yet been technically settled. From a practical standpoint it offers but little interest, for the simple reason that the question is one of theory only as to whether these losses have occurred in the

diffusion battery or during some subsequent manipulation. According to CLAASSEN, during the working of a diffusion battery, only very small sugar losses can occur, as, owing to the special conditions of the battery's working, sugar is first inverted before changes of any kind occur. No appreciable quantity of invert sugar is noticeable with healthy beets due to the rapid working of a battery; furthermore, a slight increase of invert sugar percentage could be attributed to the formation of the reducing substances through decomposition of the non-sugar. It does not seem rational to maintain that the invert sugar, which is the outcome of micro-organisms, should be again decomposed by bacteria during the short interval of diffusion.

There must be uniformity in methods of analysis,[1] otherwise the results obtained are not computable and certainly not comparable. To meet the demands of several French manufacturers it was decided that the Secretary of the Association of Sugar Chemists of France should receive weekly from about fifteen factories, designated by numerals, not by name, reports on some thirty or forty details, such as purity, saline, coefficient of juices, massecuite, etc., compile these data upon one sheet, and return it to all who had taken part in this system of control. By this means one manufacturer could compare the beets he was working, his losses, his yields, etc., with those of his competitors. However, a cursory glance at such a table shows that it has very little practical value. Furthermore, the analysis of beets taken as samples from piles gives only a rough approximation of the average sugar contained in, perhaps, 1000 tons per diem, as worked at some factories.

On the other hand, if the juice from the battery be accurately analyzed at regular intervals, and its volume, which may be measured with almost mathematical accuracy prior to carbonatation, is known, a point of departure that may be considered reliable is established. But how make allowances for the air bubbles? How estimate the volume of a substance when the surface is irregular and uneven? In those factories where crystallization in motion is adopted, and second-grade syrups are returned to pan, an estimation of the accurate percentage of sugar in a massecuite would be impossible.

Even admitting that this information could be obtained, the comparison of one factory with another would not be possible, as

[1] S. B., March, 1896.

the analyses are all made by different chemists and under different conditions. SACHS, who is the promoter of the idea of the comparative sheets just mentioned, organized another system of control that has all the advantages of previous schemes and none of the disadvantages. His method for estimating the percentage of sugar, etc., in stage of manufacture is most simple and very exact. The first-grade sugar is weighed on scales, and a sample of this sugar is polarized; the polarization obtained, multiplied by the number of kilos of first sugar, gives the weight of pure sugar. The second massecuites from syrups swung from centrifugals are sufficiently fluid to be measured, and, the density being determined, the weight is obtained. A sample is taken and polarized, and, by again multiplying this percentage of pure sugar by the weight of second massecuites, the number of kilos of pure sugar they contain is determined. By adding the weight of pure sugar contained in first-grade sugar to the pure sugar of the second massecuites, we have accurately the quantity of sugar the massecuite contained when it left the pan. By subtracting this weight from that found in the raw juice, the sugar lost during manufacture is determined, and hence a control which is practical and simple is obtained. In order that these results may be comparable, SACHS has organized a special laboratory with several assistants. There are many Belgian and Dutch contributors to this mutual system of control, all being, however, unknown to each other.

The manufacturer must fill out certain forms, and very accurate information must be furnished as to the volume of diffusion juice and its sugar percentage, weight of first-grade sugar and its polarization, volume of second massecuite sugar in residuum pulps, sugar in scums, etc.; there must also be sent an average sample of first and second massecuites. In return, after a reasonable interval, the manufacturer receives an elaborate table, the outcome of the work at the control laboratory. These data constitute a check on the work done by the chemist at the factory, and also point out any error that may have been made during the week's working. As each subscriber knows his own letter in the table, he can accurately compare his work with that of other manufacturers. The figures are comparable, for they have all been obtained under one head and by the same chemical method of analysis, which has never been done before to the writer's knowledge.

The question of **technical bookkeeping** is an important factor towards successful beet-sugar manufacture. It should include all

the technical data, not only the notes of the factory and their results, such as extracts from laboratory notes, but all other notes upon which the science of beet-sugar extraction depends. Such details as fuel, coke, limestone, lime, filtering cloths, hydrochloric acid, oils, etc., should be itemized, also the number of bags of sugar and to whom they have been delivered, details respecting siloing and keeping of beets, sugar analysis, etc. No special specified details can be given, as the conditions are very different for each factory, and no special notes of slight importance should be considered.

CHAPTER III.

SLICING STATIONS.

In order to save the cost of transportation of the beets from distant farms to the sugar factory, Linard made the excellent suggestion that the juice of the beet rather than the root itself be transported. In the first installation of the kind, made in 1867 at St. Aquaire, France, the beets were rasped at that station, then the juice was pressed out and sent through underground pipes to Montcornet, a distance of about eight kilometers. After diffusion came into vogue, and difficulties in supplying sufficient beets for a large-sized sugar factory arose, the distant slicing stations became more popular, and in most of the very large beet-sugar plants in Continental Europe the system continues in use. For example, the factory at Wanze, Belgium, with a daily capacity of 3500 tons of beets, has 14 slicing stations, and the central factory of Escaudoeuvres, France, with a daily capacity of 3000 tons of beets, has 16 rasping stations.

Evidently one of the great advantages of the method is the decreased cost of sugar production, and it has none of the disadvantages of the smaller factories, as the residuary cossettes are readily sold to adjoining farmers. The slicing stations have their flumes for beets, washers, slicers, diffusion battery, cossette presses, pumps, decanting vats, etc. To the juice leaving the measuring tanks is added about 1 per cent of quicklime, used in the dry condition or as a milk of lime. The juice thus limed will undergo no change during the transit through the pipes from the slicing station to the central factory, and upon its arrival the lacking lime necessary for defecation is added. The limed juice is forced into the pipes by a double-acting plunging piston, and the flow is regulated by large accumulators, such as are employed for hydraulic presses. If the juice pipe makes a bend corresponding to less than an atmospheric pressure, the juice would form an equilibrium, thus working very like a syphon. Very little force would be necessary if the central

factory were posted at the lower end of the pipe. These conditions would not remain the same if the elevation were more than 10 meters, in which case the weight of the juice in the lower pipe could not rise the juice to the height of 10 meters. Consequently the work to be accomplished by the pump would be the total elevation less 10 meters. But it must be remembered that beet juice, with an entirely different density from water, is being handled. If D is the density of the juice, the height to be deducted would be $H=\frac{10 \text{ meters}}{D}$.

Many instances could be cited in which the juice is carried over elevations of 100 meters. It may happen that the central factory is at a lower elevation than the annex. It is generally found desirable to allow for extra pressure at the start by giving the pipes an additional thickness some few feet from the annex. There need never be much fear of the pipes bursting, owing to the comparatively small velocity of the juice during transit. There is considerable friction, which must be allowed for; but this may, in a measure, be overcome by using pipes of a larger diameter than is apparently needed.

The following table gives some important data respecting the pipes used at the Coulommiers factory in France:

Dimensions of Piping, etc., for Transporting Juice to Factory at Coulommiers, France.

Name of locality.	Length of pipe.	Volume of juice per meter.	Total volume of juice in pipe.	Interior diameter of pipe.	Pressure.
	Meters.	Liters.	Hl.	Mm.	Atm.
Jouy to Prevert	2209	9.16	202.34	108	9
Vaudoy to Prevert	2044	11.30	230.97	120	
Rozoy to Vaudoy	8495	7.85	666.85	100	
Prevert to Coulommiers	17236	17.67	3054.36	150	
Total juice in pipes	....	....	4154.52		

In France the cost of pipe line is very variable, but, from information collected, it may be said to be $2600 per mile. Suppose the pipe to be 100 mm. in diameter, and the annex to be of rather large size: for twenty miles this would involve an outlay of $50,000. without taking into consideration the cost of the annex, which would not be much less than $100,000 to handle several hundred tons of beets per diem. A very simple calculation would show that the

outlay is a profitable one, especially in countries where, as in Utah, the beets are cultivated by irrigation. During several months of the year, the pipes may be used to carry water for irrigating lands that might otherwise be almost worthless. Water needed for the annex factories in an emergency could be placed in reservoirs and used when needed.

Evidently the diameters of pipes used should not be too small, otherwise the necessary pressure would be excessive. An idea of the pressure resulting is given in the foregoing table. Sometimes the pipes used are 18 miles in length. The kinds most used are in sections of about three meters that fit into one another, the joints being filled with lead. The pipes generally follow the undulations of the roads, and in some cases they are placed alongside the railroad, but 80 cm. underground, so as to be protected against frosts. In case they are near the roads, at all the higher portions of bends air purgers should be placed, so that all air and gases can make their escape, as they would otherwise form serious obstructions in the circulation. At the WANZE sugar factory, overseers continually go back and forth to detect any irregularity. They are in constant telephonic communication with the repair station, so that the necessary appliances for correcting any difficulty may be furnished at once.

These pipes should now and then be cleaned. The DE LOYNES method is very simple and practical. A section of the pipe that is to be cleaned is taken out, a wooden ball of a diameter of 12 to 15 mm. less than the inside of the pipe is introduced, and the portion of pipe is then put back in position. Pressure is exerted, and the ball in revolving pushes all sediments before it. The operation should be repeated several times. The pipes from the different slicing stations all meet in front of an iron tank; but, in case of difficulty arising at one of the stations, communications with it are cut off.

Besides mechanical losses, some authorities claim that there are sugar losses in this mode of juice transportation. According to PELLET, SAILLARD, and BEAUDET, the sugar destruction, even after 90 hours, is so small that it cannot be considered; after 120 hours it is 0.40 per cent, and after 144 hours it becomes 1.6 per cent. As there are very few rasping stations where the juice remains in the pipes more than 24 hours, the sugar destroyed need not be considered.

Juice cisterns.—MAUMENÉ proposed that to beet juices there be added 0.3 to 0.5 per cent of lime, the juices to be subsequently

kept in large reservoirs or cisterns. It was claimed by this authority that the juice could thus be kept for six months without undergoing the least alteration, and that, when subsequently submitted to the carbonatation process, the desired results as regards decoloration, etc., would be realized. It is to be noted that considerable capital would be required to carry out this plan.

Another original idea was practically tried in Denmark. It consisted in having rasping stations run their juices into boats having special cisterns suited for the purpose. These boats were then sent to their destination and the cisterns emptied. This idea is worthy of serious consideration, but it demands that numerous waterways be at one's disposal. Of late, beet juice has been transported in France in railroad cars.

CHAPTER IV.

SUMMER WORK.

THERE is always complaint among capitalists that the investment in a beet-sugar factory remains idle nine to ten months of the year. Evidently, in cases where large crystallizing tanks are used, a certain number of weeks are necessary to work off the product; but, by recent methods of working, the campaign ends a few days after the working of the beets, as the final residuary molasses ceases to be of value for sugar-extracting purposes.

Beet-sugar manufacture is always in full activity during the winter months, for then the beets are brought fresh from the field or are siloed. The campaign proper is a very fatiguing one, and is a great strain not only upon all persons connected with it, but also upon the machinery. When the last roots have left the slicer, and all the sugar has been removed from the factory, work of another kind must commence, and that is a thorough cleaning of all the appliances, some of which are removed entirely, to be replaced by such others as progress may demand. These changes are of far greater proportions than is generally supposed; in fact, after an interval, say of ten years, hardly a single piece of machinery of the original plant remains.

It is desirable to give the machinery a preliminary cleaning, and later to complete this by a very thorough washing, etc., and a very careful examination of every detail, so as to determine whether repairs are necessary or not. The important repairs that must be executed in the machine shop should, as far as possible, be placed in the constructor's hands in the spring, at a time of the year when there is very little going on. Under these circumstances, more attention may be given and the apparatus delivered and replaced in position long before the sugar campaign begins. The repairs and small installations that may be made in the factory should be executed by mechanics who work on yearly salaries, and have

ample time to carefully do the necessary patching. It is most desirable that the factory be independent of outside machine shops.

It frequently happens that the buildings of a beet-sugar factory form the nucleus for a new town that is built around them. Such a factory is seldom or never built close to a large manufacturing town; for the area generally covered is vast, and country lands are always cheaper than such as can be found in a town, however small its population. In most of the European factories there are well-organized machine shops, which can undertake nearly all the repairs necessary. The conditions for small plants are, of course, entirely different, but as these are rapidly disappearing they need not here be considered. All the pieces of machinery, valves, cocks, etc., are carefully numbered before being turned over to the repair shop.

After the various parts of the appliances have been examined and repaired they should be put together, and the precaution taken to thoroughly grease their surface, so as to protect the iron against rust. To keep off dust, etc., it is found advantageous to cover them completely with cloths during the several months they remain idle before the campaign commences.

In this question of repairs special stress should always be placed on looking after such portions as are hidden, and such as could not be repaired during the sugar campaign, by which plan numerous complications are obviated. Just as boilers are examined at regular intervals to ascertain if they leak, or if they can withstand the greatest pressure to which they are to be submitted, so multiple effects and vacuum pans should also be tested and overhauled. The coils and the chambers that are heated with live steam should be submitted to one to two atmospheres of water pressure, or at least to the maximum pressure of the steam employed. In those appliances heated with low-pressure steam, the pressure of the water from the diffusion reservoir, which corresponds to about one atmosphere, is sufficient. For these tests the entrance, emptying, and purging cocks should all be in their respective positions. It is especially recommended to test by this water pressure not only the heating chambers, but also those portions of the multiple effect where the boiling of the juice is effected, and where, consequently, the acid clearing is accomplished.

Malander says that it is desirable to ascertain whether the tubes of the multiple effect are eaten away, and for this purpose several of those forming part of the tubular cluster should be taken out

and thoroughly examined. This will decide whether or not the whole series must be taken out and replaced by new ones. The ones most liable to be eaten away are those in the vicinity of the place where the steam enters the effect, or where the ammoniacal water is removed.

This work is generally done during the summer months. If the tubes of a vertical effect are not in a bad condition, they are thoroughly brushed inside, so as to remove all deposits. In the case of horizontal effects, the pipes are all taken apart, scraped, and cleaned in some rotating device in which, through friction upon one another, they are not only cleaned, but also polished at the same time.

During the summer months all the lime deposited at the sides and at the bottoms of the carbonatation tanks is scraped off. In some factories this operation is performed immediately after the campaign has ended, and before the deposits have had time to harden. Their removal then is much easier. Otherwise this work is preferably done when the deposit is very hard and scales off by simply knocking on the outside of the tank with a mallet, but some care must then be taken that the sheet iron is not injured. The flues connecting with the carbonatating tanks must also be cleaned. The liming and mixing tanks, the carbonic-acid gas distributors, the pipes connecting with filter presses, and the filter presses in all details, must all be scraped to remove deposits and then cleaned. To gain time and save labor it has been proposed to use a solution of hydrochloric acid; but if the deposits are thick it is doubtful if the money saved in wages will not be expended in acid. In factories where calcareous waters are used for the condenser, the moist-air pump, the barometric pipe, and the exit pipe to the flumes, etc., become thickly coated with lime, and must be unmounted in detail to remove these deposits, as they may cause difficulties during the sugar campaign. The same remark also applies to the gas washer connected with the lime kiln. All the pipes, and parts through which sulphurous acid circulates, should undergo an examination. All valves and cocks should be taken apart and thoroughly examined, and all defective portions repaired or removed.

As the sugar campaign terminates before the end of the winter, the cold enters the factory and freezes all water that may have been left in any of the machines; hence special attention should be given to the steam cylinders and piping and valves connected with

same. The freezing in these parts would burst them, and cause considerable expense for repairs.

In case it is thought desirable to paint the piping, it is recommended to select different colors, to indicate the purpose for which they are intended. There are many advantages for the surveillance in this arrangement, as each hot-water, juice, or steam pipe is thus plainly marked.

It is desirable to have arrow indications showing the direction of the circulation of the liquids. In certain factories the arrow in question is cast with the valve, and the purpose of each is explained by a small sign.

Supplies in reserve.—According to the existing local conditions, one is obliged to keep on hand a certain number of workmen, who are kept actively employed during the summer months. They should look after several issues relating to supplies in reserve. Provision must be made to have all new supplies of coal and coke, limestone, etc., in place when the machinery is set in motion, as the yards of the factory are too crowded at that time, with the going and coming of vehicles for beets, to allow any space for other supplies. The filter-press cloths must all be mended, and the new ones properly hemmed. A supply of oil for lubrication, and a number of other articles, must be kept in sufficient quantities to prevent any interruptions whatever after the slicing begins.

Remounting the machinery.—As the cleaning of the various parts of the machinery progresses, they are remounted and put together in their respective positions, and are then submitted to a preliminary test to ascertain whether there are any special defects. The pressure at which the various pipes, etc., are tested is somewhat higher than it is when the factory is in full activity. Each piece of apparatus and machinery is made to work separately, and each one is first tested without accomplishing any work, and then at the maximum strain that it will be called upon to sustain. Pumps should give their greatest efficiency. These precautionary measures help to make sure that power is not being wasted. The joints of all the valves of whatever kind should be tested. All the thermometers and pressure gauges should be compared, to ensure a thorough uniformity in their reading. When all is ready the factory is started; but, instead of juice, water is used, which enables one to ascertain if the joints are leaky. The duration of this water test varies from factory to factory; but, under close observation, about 48 hours appear to be a reasonable average.

After this water test the appliances are emptied and then finally cleaned. As regards this experiment, it is to be noted that it should be done neither too soon nor too late. If too soon, certain parts may again become rusty and leak before the campaign begins; and, if too late, some defects may be discovered at the last minute, and, to make the needed repairs, the first slicing of the beets would have to be postponed. It is generally customary to make the water test about three weeks before the intended starting of the campaign, in which case the belting, etc., may then and there be stretched on the pulleys. In some factories visited, the campaign follows immediately upon the water test. While, in case of emergency, a lime kiln can be brought in full activity 4 hours after lighting, it is advisable to start it very slowly at the beginning of the campaign, so as to prevent any cracks in the firebrick work. Most of the factories light the kiln 48 hours before slicing.

CHAPTER V.

CALCULATIONS FOR A BEET-SUGAR FACTORY, AND FORMULÆ.

The calculations for a beet-sugar factory involve many factors, and the only way for the reader to follow them in detail is to take some examples given by several of the leading experts and to draw practical conclusions from the methods adopted and the results. HORSIN-DÉON starts by considering a 300-ton plant. The beet *sheds* and *silos*, to hold the roots to be sliced per 24 hours, should have a capacity of 540 cb. m. If the beets are piled up in the yards to heights of 2 meters, the actual space needed is 300 sq. m., or 17.32×17.32 meters per day's slicing. The area, 300 sq. m., should be multiplied by the number of days the campaign is to last, supposing the entire crop to be delivered before bad weather sets in.

Silos, made as is customary in Continental Europe, have a width of 3 meters at their base, and a height of 1.5 meters; and their volume is equal to 2.25 sq. m. $\times L$ (L representing the length of the silo). Consequently 300,000 kilos of beets demand a silo $\frac{540}{2.25} = 240$ meters in length. It is generally customary to arrange that two silos will hold the slicing for one day. As a space of two meters is left around them, the total area occupied for a per diem working is 1200 sq. m., and this does not take into consideration the road over which the beet wagons and cars pass upon reaching the factory.

Beet washers.—Beet washers for a 300-ton plant demand 12 HP.

Beet elevators.—After the beets are washed they are carried to the upper floor of the factory. For this purpose a height of 15 meters demands 1.5 to 2 HP.

Diffusion and beet slicing.—It is supposed that the diffusion battery consists of 14 diffusors, yielding very dense juices. If 10 diffusors are emptied per hour, there will be 1250 kilos of cossettes per diffusor; and, supposing that there are 56 kilos of cossettes per hl., the diffusors would have a capacity of $\frac{1250}{.56}=22.3$ hl., or, in round numbers, 25 hl. Consequently a battery of 14 diffusors of 25 hl. each would permit the handling of the beet slices under very favorable conditions. For a battery of this kind, one slicer is sufficient. A pump connected with the diffusion battery, the capacity of which is 10,000 hl. of water raised 20 meters per 24 hours, requires 3 HP., to which must be added the resistance of the maching and the piping, which approximately doubles the figure. A total of 120 HP. for the washers, elevators, slicers, pumps, etc., must be furnished in the service of diffusion.

The calorizators are of a tubular type, and are supposed to be heated either with live or exhaust steam. A heating surface of 4 sq. m. is sufficient. But if the steam is taken from the multiple effect, then 6 sq. m. would be needed. Three hundred tons of beets sliced per diem would give 360,000 liters of diffusion juice. If we suppose that the cossettes fall into the diffusors at 10° C., and leave after the sugar has been extracted at 40° C., with the water at the same temperature, then the 360,000 liters of juice heated to 30° C. would absorb 10,800,000 calories, and 300,000 kilos of beet cossettes, for which a specific heat of 0.6 is allowed, would demand $300,000\times30\times6=5,400,000$ calories, or a total for the diffusors of 16,200,000 calories, representing 25,312 kilos of steam per 24 hours, or 1055 kilos per hour. To this must be added the caloric lost in the waste water. Ten diffusors per hour, containing 10 hl. of water, equals 100 hl. of water, which, at a temperature of about 20° C., or 200,000 calories, equals 312 kilos of steam. Allowance must also be made for the reheating of the sheet iron of the diffusors each time they are filled. Consequently for the diffusion there is needed a total of 1500 kilos of steam per hour, or 100 sq. m. boiler surface.

Height of tank giving pressure to battery.—If the road travelled by the liquid from the water tank to the juice tank is considered, it becomes evident that when the ten diffusors are working, having 2.6 meters in height, for example, their calorizators, the piping from the tank, and the pipe leading to the measuring receptacle, all considered collectively, have a length of 70 meters, and some-

times more. There are certain losses of head that cannot be estimated. Even to overcome the resistance of the diffusion battery when empty, the water should rise about 4 meters in the pipe of the measurer. All facts taken into consideration, a height of at least 10 meters is needed for the water-pressure tank connecting with the battery. Under all circumstances the calculation for the sections of the pipes should allow a velocity of water and juice of not more than 40 to 50 cm. per second, rather less than more, and in the cocks, etc., efforts should be made to decrease this velocity to 25 cm. per second. In the case of 360,000 liters of water necessary for diffusion, the piping should have a total diameter of about 120 mm.

Carbonatation.—The first carbonatation with gas at 25 per cent lasts one hour, and the filling and emptying one-half hour. A carbonatation tank may be used 16 times in 24 hours. In order to handle a maximum of 4000 hl. of juice, there would be needed a tank capacity of $\frac{4000}{16}=250$ hl.

It is recommended to use at least five first-carbonatation tanks, one being filled, two working, one being heated, and one emptied. It is important to have two carbonatation tanks in activity, so that the working of the gas pump may be regular, as one tank has its cock fully opened, while the other, at a critical moment, is only half opened, owing to excessive frothing, etc. If reheaters are used before carbonatation, four tanks are sufficient. As two tanks are working, their active capacity will be 125 hl. The second carbonatation lasts twenty minutes, or forty-five minutes including the filling and emptying. One carbonatation tank may be used 32 times in 24 hours, giving a capacity of $\frac{400}{32}=125$ hl. As the working is very regular during the second carbonatation, three carbonatating tanks of 125 hl. will be sufficient to handle the juice of 300,000 kilos of beets.

Surface of coils of the carbonatation tanks.—If 4000 hl. of juice are to be heated from 40° to 85° C., including the milk of lime added, or 166 hl. per hour, this will demand $16,600 \times 45 = 747,000$ calories, or $\frac{747,000}{654}=1142$ kilos of steam per hour at 5.5 kilos pressure. This may be called 1200 kilos, allowing for the condensation in the piping, and this quantity of steam requires 80 sq. m. of boiler-heating surface. The carbonatation tanks contain 125 hl.

of juice at 40° C., and must receive 12,500 (85–40) = 562,500 calories in ten minutes. With steam at 5 atmospheres, there would be needed 14 sq. m. of coil-heating surface. In the second carbonatation tanks, where the heating is from 80° to 100°, or 20° C., there are needed 9 sq. m. of coil-heating surface to heat for ten minutes.

Lime.—As an average of 2 per cent of lime is used for the first carbonatation, and 0.6 per cent for the second, or a total of 2.6 per cent, if 300,000 kilos of beets are to be handled per 24 hours there would be needed 7800 kilos of lime, or 8500 to 9000, allowing for losses, that is, 375 kilos per hour. In order to produce that quantity of lime it would be necessary to handle 18,000 kilos of limestone per diem, or about 15 cb. m., and 1500 kilos of coke, or a fraction less than 4 cb. m. A lime kiln of about 50 cb. m. capacity must be used, or two small Belgian furnaces producing 200 kilos of lime per hour. Two kilns are better than one, as every mishap will then not bring the factory to a standstill; on the other hand, one kiln is easier to connect with the pump. In case of two kilns, there would be needed two washers, and a sluice with a perfect joint placed after each, the sluice to be regulated so that the draught shall be satisfactory in each kiln. The supply of limestone needed for a 90-day campaign is 1,700,000 kilos, or 1400 cb. m., which may be piled up under weather-protecting sheds.

Milk of lime.—If the milk of lime is at 20 per cent, 80 kilos of water for 20 kilos of lime, 9000 kilos of lime demand 40 hl. of water for their slaking, and 360 hl. of sweet water with which the slaking is done, or 400 hl. of milk of lime. To raise this to the carbonatation tanks demands 4 HP.

Carbonic-gas engine.—If we suppose that the gas from the kiln contains 30 per cent of carbonic acid, the pump must exhaust about 20,000 cb. m. in 24 hours, the quantity varying with the temperature. If the machine turns at the rate of one revolution per second, the cylinder must have a diameter of 800 mm. to accomplish the work connected with carbonatation. The work necessary to put this machine in motion will correspond to raising the juice at a height equal to the depth at which the distributor is under the juice level. The carbonatation tanks are filled with juice at 1.50 m. in height, and the pressure exerted on the piston will be about 750 kilos for each semi-revolution, demanding 33 HP. It is admitted that at least 40 HP. should be used in order to overcome the resistance.

Scum pumps.—These pumps must force 4000 hl. of juice through the filter presses at a pressure of 3 atmospheres, and for this a force of 140 kilos per second, or 2 HP., is needed. As a general thing, these machines are very much more powerful, owing to special and exceptional resistance which must frequently be overcome. Two machines are frequently coupled on the same shaft, so as to overcome the dead centres of the cranks. As two pumps are needed, not less than 16 HP. is necessary for their satisfactory working.

Filter presses.—The scum from carbonatation represents at a maximum 12 per cent of the weight of the beets sliced, and, for the 300,000 kilos being worked per diem, it would amount to 36,000 kilos, or for the 90 days of the campaign 2700 cu. m., which must be placed somewhere to remain until the campaign has terminated. About 4000 hl. of juice must be run through the filter presses. There will be needed for full working $4\times45=180$ square meters for the first carbonatation, and $4\times15=60$ square meters for the second. It is recommended that for the first carbonatation the frames of the filter presses have an area of one square meter, which means two square meters filtering surface per frame. Ninety frames would be needed, or two large filters of 45 frames each, and a third for the cleaning, or three filter-presses. For the second filtration smaller presses may be used, with frames of 64×66 cm. About 50 frames would be needed, or two presses of 25 frames each, and a third in reserve.

Mechanical filtration.—In the PHILIPPE pocket filters, 40 hl. of juice per square meter may be filtered in 24 hours, and for this there will be needed $\frac{4000}{40}=100$ square meters. As the filtering of the carbonatation juice offers certain difficulties, 4 filters of 40 sq. m. each should be used, keeping one in reserve for the filtrate from first carbonatation, and using 3 filters of 40 sq. m. for the second carbonatation filtrates, which are more readily filtered.

Evaporation.—To evaporate 4000 hl. of juice and condense it to the consistency of a syrup of 27° Bé. there would be needed a triple effect of 400 sq. m. heating surface, or three compartments of 133 sq. m. in each. It is better, however, to have a quadruple effect with multiple-effect heating.

Reheating the syrups.—Upon leaving the multiple effect the syrups are at a temperature of 50° C., and must be heated up to

about 100° before being filtered. The 4000 hl. of juice will give nearly 800 hl. of syrup, with a specific heat of about 0.6 and a density of 1.3. This syrup must receive $80,000 \times 50 \times 1.3 \times 0.6 =$ 3,240,000 calories, that is, 5000 kilos of steam per 24 hours, or 208 kilos per hour.

Filtration.—Through the PHILIPPE filters 20 hl. of syrup per square meters may be run in 24 hours, and this will require $\frac{800}{20} =$ 40 square meters of filtering surface. It is recommended to use three filters of 20 square meters, so as to keep one in reserve.

Vacuum pan.—The syrups upon leaving the filters are run into the waiting tanks, where they cool to 40° C. If the vacuum in the pan is about 60 cm. the syrup will boil at 69° C., and it must therefore be heated from 40° to 69°,—in other words, 29° C. must be supplied. The specific heat of a massecuite is about 0.5. The requisite steam must be furnished to raise the syrup to 30° Bé., so that as a massecuite it will contain only 8 to 10 per cent of water, that is to say, 39 per cent of the water must be removed from the syrup. From 800 hl. of syrup, or 104,000 kilos, there will be evaporated 40,560 kilos of water. Consequently, to raise the temperature of the syrup 29°, there will be needed $104,560 \times 29 \times 0.5 = 1,508,000$ calories. These calories may be supplied by means of steam at a pressure of 4 atmospheres, supposing direct steam to be used, which method is still in use. Steam at 4 atmospheres has a temperature of 144° C., and the boiling syrup will be at 69°; consequently, in passing from 144° to 69°, the steam will condense, and give up the following number of calories: $537 \times (144 - 69) = 612$. To reheat the syrup one needs $\frac{1,508,000}{612} = 2464$ kilos of steam; and to complete the graining there are needed 34,130 kilos, or a total of 36,500 kilos, or 1520 kilos per hour. HORSIN-DÉON calls attention to the fact that, as the evaporation is very much more rapid at the beginning than towards the end of the graining, there will necessarily be much more steam used when the pan is first started than when the strike is about to terminate. This enormous momentary expenditure of heat at certain periods of the day causes great difficulty in properly conducting the boilers; and it is recommended that the pan man give due notice when the operation of graining is about to commence, otherwise the entire factory might be suddenly deprived of steam. For each strike there are needed about

5000 hl. of water for the injector of the condenser. From 4000 hl. of juice there are obtained 600 hl. of massecuite, or 15 per cent. As the graining lasts for 10 hours, it would be possible to make two strikes per diem in the same pan. The vacuum pan should have a working capacity of 300 hl. Pans of this kind have a diameter of 4.50 m., and are 2.8 m. in height; they have four coils and a heating surface of 55 to 65 sq. m.

Air pump.—For a vacuum pan of 4.5 m. in diameter and 2.8 m. in height there would be needed an air pump of 500 mm. in diameter and a 550 mm. stroke. The cylinder of the steam engine should have a diameter of 340 mm., the fly-wheel making about 55 revolutions per minute. A pump of this kind requires 26 HP. Attention is called to the fact that in such cases there is every advantage of having only one condenser, and one pump for the vacuum pan and the multiple effect. A 100-HP. engine could be used, which would be sufficient for working the ammoniacal pumps, the juice and syrup pumps, etc., and would be far less troublesome than all the various complications that arise with the use of numerous machines.

Massecuite tanks.—In the case under consideration (slicing 300 tons of beets per diem) the tanks should have a total capacity of 600 hl.; but as the product, for one reason or another, cannot all be handled in the centrifugals in one day, the capacity must be 900 hl., and three or more tanks are needed for the purpose.

Crystallizators.—There are several types of crystallizators which can work 600 hl. of massecuite per diem and demand a force of 2 HP.

Centrifugals.—The centrifugals handle 50 kilos of massecuite, or 35 liters; and to handle 60,000 liters of the product there must be 1700 swing-out operations in 22 hours, or 78 per hour. If each operation lasts ten minutes, 13 centrifugals would be sufficient for the work. Each centrifugal requires about 1.5 HP., making a total of 20 HP.

Vacuum pan for seconds.—There will remain about 150 to 200 hl. of second massecuites, and, as the graining by modern methods is comparatively slow, the pan should have a working capacity of about 100 hl. If no crystallizator is used, the capacity of the tanks holding the grained after-product should be 10,000 hl., so as to contain about one-half of the entire amount manufactured. There are needed 5 to 6 centrifugals for the massecuite seconds.

The water needed for a 300-ton beet-sugar plant per 24 hours is given by HORSIN-DÉON as follows:

	Hectoliters.
Washer	300
Diffusion	4,000
Milk of lime	400
Filter-press washing	400
Evaporation (triple effect)	24,000
Vacuum pan	10,000
Total	39,100

This means at least 40,000 hl., taking into consideration the water necessary at the factory for various purposes. The waters are collected in various reservoirs connecting with the pumps. The above calculations suppose that 10,000 hl. are needed for the diffusion and the operations conected with it. If the ordinary condensers for the triple effect and the vacuum pan are used, the 34,000 hl. that are necessary may, whenever possible, be drawn from a well. If dry pumps are used, the water is forced up into reservoirs, placed at an elevation of at least 10 meters, by a pump demanding for its working at least 53 HP. The various resistances of the machine and the losses must be allowed for, so that for this work an engine of at least 60 HP. is needed, and to this must be added the water necessary for the hydraulic transportation; for which purpose the 34,000 hl. from the condensers are used. There is needed still another pump to raise this water a few meters. If we suppose that 3 meters is the difference of level, then a 20-HP. engine is sufficient.

The total quantity of steam needed for a beet-sugar factory slicing 300 tons of beets per diem, and working with a triple effect, is about 14,000 kilos per hour. If a quadruple effect had been used, the steam consumption per hour would have been 10,100 kilos. If it is supposed that a boiler makes 15 kilos of steam per hour and per square meter, there would be needed 934 sq. m. of heating surface to furnish the steam for a triple effect, and 700 sq. m. for a quadruple effect. In France a type of semi-tubular boiler of 150 sq. m. is used. There would be needed 7 boilers in one case and only five in the other.

Fuel.—If 9 kilos of steam are obtained per kilo of coal, there would be burned with the triple effect $\frac{14,000}{9} = 1555$ kilos of coal

and with a quadruple effect $\frac{10,100}{9}=1120$ kilos. The consumption for a campaign of 90 days would be 3400 tons in one case, and for a quadruple effect 2520 tons. The cubical space needed for this coal may be calculated by remembering that in one cubic meter may be placed from 942 to 1328 kilos of coal, according to quality.

Molasses.—The final molasses represents about 3 to 4 per cent of the total weight of beets sliced. There will consequently remain between 10,000 and 12,000 kilos of this residuary product per diem, or about 80 hl., that is, 7200 hl. for the 90 days' campaign, which expresses the capacity which the tanks holding it must have, unless it is sold as made or put up in barrels.

Practical Data Relating to a German Beet-sugar Factory.

(Slicing capacity, 400 tons of beets in 24 hours.)

Sheds.

Height of pile of beets above flume, 3 to 4 m.; floor space occupied by beets, 320 sq. m.; capacity, 5 to 600 tons.

Washer.

Capacity when working under normal conditions, 3 to 4 tons; length 7 m., width 2 m., velocity = 15 revolutions per minute. Force needed = 4 to 5 HP.

Carrier and Shaker.

Length 5 m., width 800 mm.; slant 2%; force needed = 1 HP

Beet Lift.

Capacity of buckets, 15 l.; number of buckets emptied per minute, 75; diameter of chain links, 20 mm.; force needed = 2 to 3 HP.

Two-beet Slicers.

Diameter of revolving plate, 1100 mm.; number of blade holders, 16 per plate; velocity, 70; force needed = 10 HP.

Diffusion Battery.

Fourteen diffusors, capacity 4500 l.; diameter of juice and water pipes, 120 mm.; pressure of steam used for heating, 0.3 to 0.4 atm.; diameter of steam valves, 40 mm.; heating surface of each calorizator, 3.3 sq. m.; water pressure 15 m.

Open Reheater.

Heating surface, 120 sq. m.; steam pressure, 0.4 atm.

Cossette Press.

Five KLUSEMANN presses; force needed = 2 to 4 HP.

Carbonatation.

First carbonatation, 5 tanks.	Height, 7 m. Actual capacity, 18,500 l. Working capacity, 4000 l.
Second carbonatation, 2 tanks.	Height, 2.750 mm. Actual capacity, 7700 l. Working capacity, 4000 l.

Lime kiln.

KHERN type; capacity 22 cb. m.

Carbonic-acid Pump.

Diameter steam cylinder, 340 mm.; diameter pump's cylinder, 700 mm.; stroke, 650 mm.; revolutions, 36 to 42; force needed = 33 HP.

Double-scum Pump.

Diameter of scum-pump cylinder, first carbonatation, 180 mm.; diameter of scum-pump cylinder, second carbonatation, 180 mm.; diameter of water-pump cylinder, 100 mm.; stroke, 400 mm.; revolutions, 36; force needed = 10 to 20 HP.

Filter-presses.

First carbonatation, 4 filter-presses, 30 frames, 800×800 mm.; second carbonatation, 2 filter-presses, 30 frames, 800×800 mm.; 4 BREITFELD and DANEK pocket filters, 725 mm.× 1000 mm. (20 frames); 2 KROOG filter-presses for syrups, 30 frames, 565×590 mm.

Evaporation.

TRIPLE EFFECT, with vertical compartments of same size, 200 sq. m. for each compartment; counter pressure of the engines, 0.40 atm.; absolute pressure in condenser, 0.1 to 2 atm.

Fore-evaporator.

Heating surface, 150 sq. m.; heated with live steam at 2.5 atmospheres pressure; pressure in juice chamber, 0.7 to 1 atmosphere.

Worthington Quadruple-action Pump Feeding the Fore-evaporator.

Diameter of cylinder, 200 mm.; diameter of cylinder of engine, 175 mm.; stroke, 200 mm.; number of strokes going and coming of each cylinder, 36 per minute; counter pressure in the fore-evaporator, 0.7 to 1 atm.; force needed = 3.6 HP.

Varied Pumps.

Tandem pumps for forcing juice into reservoir of pocket filters, and for the syrup from the compartment before the last of the multiple effect; diameter of the pocket filter-pump cylinder, 200 mm.; diameter of syrup-pump cylinder, 120 mm.; diameter of cylinder of engine, 260 mm.; stroke, 400 mm.; revolutions, 60; force needed = 10 HP.

Air-compressing Pump for Sulphuring.

Diameter of compressing cylinder, 120 mm.; diameter of engine cylinder, 90 mm.; stroke, 160 mm.; revolutions per minute, 120; force needed, 2 to 3 HP.

Dry-air Pump for Multiple Effect and Vacuum Pans (variable expansion, system MEYER).

Diameter of the pump cylinder, 700 mm.; diameter of cylinder of engine, 400 mm.; stroke, 700 mm.; degree of admission, 0.3; revolutions per minute, 60; force needed, 20 HP.; vacuum obtained, 73.5 cm.

Water Pump for the Condenser (MEYER expansion).

Diameter of pump's cylinder, 480 mm.; diameter of engine's cylinder, 350 mm.; stroke, 540 mm.; degree of admission, 0.5 to 0.6; revolutions per minute, 27; force needed, 25 HP.; lifting capacity, about 4 cu. m. per minute at 22 m. height.

Ammoniacal-water Pumps (2 tandem pumps).

Diameter of pump's cylinder, 140 mm.; revolutions, 40; force needed, 2.5 HP.

Syrup Pump Plunging Piston Drawing from the Last Evaporating Compartment. (Simple action worked by belting.)

Diameter of pump's piston, 100 mm.; stroke, 250 mm.; revolutions, 150.

Vacuum Pans. (2 pans of the GREINER type for first sugars.)

Heating surface, 80 sq. m. each; capacity, 23,000 l.; working capacity, 15,000 to 16,000 l. One after-product vacuum pan (vertical tubes): Heating surface, 60 sq. m.; capacity, 7800 l.

Crystallizators in Motion. (4 double-bottom types.) Capacity, 2×15,500 l. and 2×16,600 l.

Centrifugals. (8 PILÉ types.)

Diameter of drum, 1000 mm.; revolutions = 1100.

One Crystallizator for After-products.

Capacity, 15,000 l.; is used only for reheating massecuites in an emergency.

Eleven crystallizing tanks. Capacity, 87,000 l. each.

Centrifugals for After-products.

There are two of these, which are of the same size as those of the PILÉ model.

Steam Engines.

Special for the Diffusion (MEYER expansion).

Diameter of cylinder, 470 mm.; stroke, 680 m.; admission, 0.4; revolutions, 96; force needed, 65 HP.

Engines for Centrifugals.

Same diffusion; force needed, 55 HP.

Engines for Lighting Purposes.

Force needed, 25 HP.; SHUNT dynamos; e.m.p. = 105 volts; $I = 150$ to 200 amperes. There are numerous other engines for fresh water and boiler feeding, also several extra pumps for an emergency.

Boilers (6 tubular, DE NAEYER type).

Three with reheaters; total heating surface, 1500 sq. m. Five boilers are constantly working and one is being. cleaned

One small boiler, with a superheater, through which passes the whole live steam (system LEINVEBER), 750 sq. m.

FORMULÆ.

The tables and formulæ given herewith are those which are of special interest to the technical sugar expert. Many of them are of CLAASSEN'S own work, and not to be found in other publications and sugar text-books of reference, or, if they do appear, they in most cases are more or less altered and are incomplete.

Formulæ for the calculation of the weight of water, W, which should be evaporated from J kilos of juice of $S°$ Brix, yielding a concentrated juice, $S°$ Brix:

$$W = J\left(l - \frac{s}{S}\right).$$

Formulæ for the calculation of the quantity, Q, of concentrated juice, or massecuite, at $S°$ Brix, obtained from J kilos of juice at $S°$ Brix:

$$Q = J\,\frac{s}{S}.$$

With the view to accurately calculate the quantities, it becomes necessary to take, in the foregoing formulæ, the actual percentage of dry substances, instead of the apparent percentage.

Formulæ for the Calculation of Yields.

Indications Ft, Zt, St, dry substances in massecuite, sugar, and after-products.

Fp, Zp, Sp, polarization of the massecuite, sugar, and after-products.

Fq, Zq, Sq, purity (actual) of the massecuite, sugar, and after-products.

X, percentage of the yield to be determined.

1. HULLA-SUCHOMEL formula:

$$X=100\frac{Ft(Fq-Sq)}{Zt(Zq-Sq)}.$$

2. SCHNEIDER formula:

$$X=100\frac{Fp-Sp}{Zp-Sp}.$$

3. NEUMANN formula:

$$X=100\frac{Ft-St}{Zt-St}.$$

The formula (1) may be used in all cases, even when the swung-out after-product is diluted in various ways. On the other hand, the formulæ (2) and (3) can be used only in cases where the after-products have not been diluted during swing-out.

4. Formula relating to the saturation of an after-product.

An after-product saturated at the temperature, t, of an actual purity, q, has the following composition (water $=W$, sugar percentage Z) when the conditions of saturation of a pure-sugar solution is at the temperature $t=L_t$ (see Table 4) and that the coefficient of saturation $=c$:

$$W=\frac{q}{L_t\cdot c+0.01q},$$

$$Z=(100-W)\frac{q}{100}.$$

If it is desired to determine the composition of a supersaturated after-product, the coefficient (c) in the above formula should be multiplied by the coefficient of supersaturation (c):

$$W=\frac{q}{L_t c\cdot c-0.01q}.$$

5. Formulæ for evaporation and reheating:

(a) Total caloric of the saturated vapor, $\lambda=606.5+0.305t$;

(b) Vaporization heat of the saturated vapor, $r=606.5-0.695t$; t in this case indicates the temperature of the vapor.

(c) Quantity D of steam necessary for the evaporation of 1 kilo water when the temperature of the boiling juice is $=t_s$;

When the temperature of the vapor is t_d;

When the temperature of the condensed water is t_c:

$$D=\frac{606.5-0.695t_s}{606.5+0.305t_d-t_c}.$$

Or, again, if $t_d=t_c$, which is nearly correct,

$$D=\frac{606.5-0.695t_s}{606.5-0.695t_d}.$$

(d) Quantity D of vapor needed to reheat one kilo of juice in the reheaters, when the temperature of the vapor is at t_d;

When the temperature of the condensed water is at t_c;

When the temperature of the juice upon entering $=t_1$;

When the temperature of the juice upon leaving $=t_2$:

$$D=\frac{t_2-t_1}{606.5+0.305t_d-t_c}.$$

(e) Quantity D of vapor needed to reheat one kilo of juice through the injection of live steam, the temperature being the same as in (d):

$$D=\frac{t_2-t_1}{606.5+0.305t_d-t_2}.$$

Formula for the Condensation of Vapor.

The quantity W of water necessary for the condensation of one kilo of water of evaporation when the temperature of the steam $=t_d$;

When the temperature of the injected water $=t_e$;

When the temperature of the exit condensed water $= t_f$:

$$W = \frac{606.5 + 0.305 t_d - t_f}{t_f - t_e}.$$

Relation between Metrical and U. S. Standard Units.

	Inches.	Feet.	Miles.
One millimeter (1 mm.) =	0.03937	0.003281	......
One centimeter (1 cm.) =	0.39371	0.032809	......
One meter (1 m.) =	39.37079	3.280899	......
One kilometer (1 km.) =	......	....	0.62138

1 m. = 10 decimeters (dm.) = 100 cm. = 1000 mm.

1 km. = 1000 m.

	Meters.
One inch =	0.0254
One foot =	0.3048
One yard =	0.9144
One mile =	1609.3

One square centimeter (1 sq. cm.) = 0.1550 square inches.

One square meter (1 sq. m.) = 1550.4 square inches = 10.77 square feet.

One hectare (ha.) = 10,000 sq. m. = 2.4711 acres.

	Sq. cm.	Sq. m.	Ha.
One square inch =	6.45	......	......
One square foot =	928.81	0.0929	......
One acre =	......	4046.8	0.4047
One square mile =	......	25898.5	2.5899

	Cubic in.	Cubic ft.	U. S. Standard gallons.
One cubic centimeter (1 cb. cm.) =	0.061	......	......
One cubic decimeter or liter (1 cb. dm. or 1 l.) =	61.027	0.035	......
One cubic meter (1 cb. m.) =	......	35.317	264.2

1 cb. m. = 1000 cb. dm. = 1000 l. = 1,000,000 cb. cm.

One cubic inch	= 16.39 cb. cm.	
One cubic foot	=	28.32 l.
U. S. standard gallon	=	3.785 l.

	Grains.	Pounds.	Cwt.
One milligramme (1 mg.)	= 0.015	....	32
One gramme (1 g.)	=15.432	0.0022	......
One kilogramme (1 kg.)	=......	2.2046	......
One ton (1 t.)	=......	2204.6212	19.684

1 kg. =1000 gr.=1,000,000 mg.=the weight of 1 l. of water at +4° C.

1 ton =1000 kg.

One grain........... 0.0648 gr.
One pound .... 453.6 gr. = 0.454 kg.
One hundredweight .... 50.803 kg.
One short ton .... 907.20 kg.=0.907 met. ton
One long ton .... 1016.06 kg.=1.016 " "

One kilogrammeter (1 kgm.) = 7.2330 foot-pounds.
One foot-pound = 0.1383 kgm.

n degrees centigrade (n° C.) $=\frac{4}{5}n$ degrees Réaumur
$=32+\frac{9}{5}n$ degrees Fahrenheit.
n degrees Réaumur (n° R.) $=\frac{5}{4}n$ degrees centigrade
$=32+\frac{9}{4}n$ degrees Fahrenheit.
n degrees Fahrenheit (n° F.) $=\frac{5}{9}(n-32)$ degrees centigrade
$=\frac{4}{9}(n-32)$ degrees Réaumur.

One calorie = 3.97 U. S. heat units.
One U. S. heat unit = 0.252 calorie.

CHAPTER VI.

SOME OF THE FACTORIES VISITED.

IT is of interest to give a general outline of some of the 230 beet-sugar factories visited by the writer.

The Cambria central factory, France.—This factory, combined with several rasping stations, is the largest in France, and gives an excellent idea of what is done in beet-sugar making under the best possible conditions. The situation of the central factory is excellent; it is near beet fields, coal mines, and a stone quarry, under which circumstances the raw material used may be had under economic conditions. A canal close at hand furnishes the needed water in abundance, and affords an economic method of transporting beets from distant farms. The central factory can work, combined with the work of the rasping stations, 3000 tons of beets per diem. There are 16 rasping stations whose maximum distance from the central factory is about 9 miles; the total length of pipes is 78 miles. Each of these stations may be considered as an annex; in it 300 tons of beets may be worked in 24 hours. The beets are washed before being weighed; the washer is sunk in the ground, so that roots may be emptied into it directly from the carts. The beets are then raised by an endless chain to the official scales. The slicers used have a special brushing attachment and the cossettes fall upon an endless band and from it into the diffusors, which are arranged in two rows of seven. As the capacity of the diffusors is only 20 hectoliters, their working must be accomplished with considerable celerity. The water from an upper reservoir comes in contact with the cossettes, which are soon exhausted of their sugar. Each diffusor holds about one ton of cossettes, from which there are drawn 11.3 hectoliters of juice at a temperature of 25° C. The residuum cossettes fall from the diffusors into a pit beneath the battery; they are carried from this by an endless chain with buckets, and emptied into a trough containing a revolving

helice, which distributes the product into four KLUSEMANN presses, preparatory to being fed to cattle.

The sanitary laws in the Department du Nord, France, are most severe respecting the emptying of waste water into running streams, and the entire waste water from the factory is consequently distributed upon adjoining lands. The juice from the annex factories is pumped into the large reservoir, 4000 hectoliters capacity, of the central factory. It is then run through a tubular heater, receiving its steam from the third compartment of the triple effect, and is subsequently received in the four carbonatation tanks, having each a capacity of 500 hectoliters. The two second carbonatation tanks have also 500 hectoliters capacity; their heating and carbonic-acid distributors offer no features of special interest. The carbonatated juice is run through 22 filter presses with 840 frames. The scum pumps are automatic and cease working at a pressure of 3 kilos. This juice is again filtered in pocket filters and is run into the triple effect. The total heating surface of that apparatus is 4000 sq. m. The first compartment has a capacity of 683 hectoliters; the second, 872 hectoliters; the third, 1052 hectoliters. It is possible to evaporate 3200 to 4000 tons of juice to a thickness of 25° Bé. in 24 hours.

The triple effect is worked on a new basis, which consists in drawing the juice into the third compartment instead of the first, the object being to eliminate at once the ammoniacal vapors, which are so destructive to the copper tubes in the first and second compartments when working by the customary methods. A special pump forces the juice into the first compartment, under which condition it becomes the second in the series; the evaporation thus terminates in the second compartment, which becomes the third. Two pans of 1077 hectoliters capacity are needed for graining, but only 680 hectoliters of syrup are worked at a time, this volume being that of the waiting tank for syrups. The graining lasts nine hours, including the emptying of pan. The massecuite is distributed into the centrifugals by a special automatic apparatus. There are six rows of seven centrifugals, 28 of these being for first-grade sugars and 14 for second grade. The swing-outs have a specific gravity of 36° Bé. They are diluted to 22° Bé., and are then grained for 12 hours.

The lime kiln of the CAMBRIA central factory has a capacity of 580 cu. m., which is not large enough for the work to be done. This plant with its rasping stations gives employment to 2000

men and children and turns out more than 300 tons of sugar per diem.

Venizel.—This factory is interesting as having been among the first to introduce the GROSSÉ process.

At VENIZEL the juices extracted from the beets during diffusion at 30° C., and having a density of 5°, are combined with lime until the alkalinity corresponds from 22 to 25 grams per liter; the temperature is then raised to 70° C. by being run through a heater receiving the vapors from the fourth compartment of the evaporating apparatus. The juices are then run into the first carbonatation tanks (which operation continues until the alkalinity corresponds to 0.1 gram per 100 cu. m., at a temperature of 90° C.), and then through a filter press, from which they flow into the second carbonatation tanks, the liming being continued until the alkalinity corresponds to 0.05 gram per 100 cu. cm., the carbonic acid reduces this alkalinity to 0.03 gram per cu. cm., and the juice thus treated is boiled and twice filtered. The hot syrup upon leaving the evaporator is at 25° Bé., and to it are added the second-grade remelts, the whole being then submitted to a sulphitation. This operation is continued until the product is nearly neutral, when the syrup is reheated and submitted to a mechanical filtration before entering pan. The working in pan offers no special interest. The massecuite, when worked in centrifugals, gives one grade of superior white sugar.

The swing-outs, or first syrups, are again put through a sulphuring until neutral. The mechanical filtering under about one meter pressure is the next operation, and the final one before entering the waiting tank in connection with the GROSSÉ pan. In these tanks the temperature is kept up by a system of steam injection.

The GROSSÉ vacuum pan is rather higher than the regular apparatus. In the interior and on the axis of the pan is a vertical shaft with arms, used as agitators, which are placed at distances from each other varying with the type of pan; the motion is given to the shaft by gear wheels, while at the lower part of the pan are arranged a series of steel coils, through which steam circulates. At the VENIZEL factory 250 tons of beets are worked per diem, and two pans were used, having each a capacity of about 240 hl. of massecuite. Beneath these appliances is arranged a mixer of a capacity corresponding to one strike; from it the product is run into centrifugals. The product to be worked had a purity of 78 to 83. The graining is accomplished without the slightest difficulty, but frequently toward the end of the operation, as comparatively

rich syrups are added, false grain is necessarily formed. This may in a measure be overcome by using the molasses from a previous operation instead of the syrup. From this time forward the process is very simple. Into the GROSSÉ pan are drawn the first-grade swing-outs, and the volume of the product is sufficient to make a very small strike, which is kept slightly fluid at the end.

The operation now consists in allowing the mass to gradually cool to 50° C., during which period enough water must be evaporated to keep the product at a saturation point. In order that the work be entirely satisfactory it is necessary that the evaporation in question be extended over the longest possible period. If the regular graining lasts 18 hours, the final exhausting period should continue for 40 hours. The results obtained at the factory in question were 12.2 per cent white sugar and 4.44 per cent molasses containing 44 per cent of sugar. The final sugar expressed as refined was 12.5 per cent of the weight of the beets worked. The average composition of all the molasses obtained was: saline coefficient, 5.10; purity, 60.5. The resulting massecuite by the GROSSÉ method was easily worked in centrifugal. The second-grade sugars obtained had crystals of an average size and were very dry. It is important to note that in consequence of the special location of the second series of centrifugals at the VENIZEL factory it was essential to produce very dry sugars, so they would not clog the carrier during their passage to the upper floor. The result was in this special case that the second-grade syrups were very much richer than they would be in other well-combined plants working by this method.

The Chevresis-Monceaux factory.—This factory works from 18,000 to 20,000 tons of beets during the campaign. Farmers are the principal owners of the enterprise; they are paid for their beets at prices that depend upon the density of the juice and the market selling price of sugar. Residuum scums and pulps are purchased at prearranged prices.

Beets as they arrive in carts are weighed and then emptied into special covered silos, the bottoms of which communicate with five hydraulic carriers 400 feet long. They are raised to the washers by an endless screw, and a centrifugal pump carries the water from the washers to the adjoining fields. After washing, the beets are thoroughly brushed, then officially weighed. The slicer has a diameter of about 1.40 meters. The diffusors have each a capacity of 24 hectoliters, and are heated by tubular calorizators. The diffusion is conducted at a temperature of 70° to 75° C. Each

diffusor has 250 grams of sodic carbonate added before filling. From the diffusors is taken 124 liters of juice per 100 kilos of beets. The total loss in sugar during diffusion is 0.20 per cent of the weight of the beets. From each diffusor a sample of fresh cossettes is taken for analysis to determine the amount of sugar entering the factory.

The sulphurous-acid treatment commences on the raw diffusion juices, which are taken into special measuring tanks, from which they are run into lead-lined cylinders. The sulphurous-acid gas, after having passed through the juice, escapes outside of the factory. The juice becomes considerably decolorized, and 2.4 kilos of lime per 100 kilos of beets are added, after which it is forced through special heaters at 65° C., heated with vapors from the second compartment of the multiple effect. The carbonatation that follows continues until there remains 0.09 to 0.092 gram of calcic oxid per 100 cb. cm.

The juice and precipitate is filtered under pressure in filter presses. The filtrate is run through linen cloths and limed again. Heating to 95° C. is the next operation. This is followed by the second carbonatation, when the saturation is continued to 0.067 or 0.068 gram of lime per 100 cb. cm. of juice. Special pumps force the doubled carbonatated juice through the second series of filter presses. The scums are mixed with the troubled juices of the first filtration, and the clear juice is filtered in special mechanical filters before the third carbonatation, where it is mixed with the swung-out syrups from centrifugals properly treated by sulphurous acid. The saturation must continue until there is an alkalinity of 0.024 to 0.026 gram per 100 cb. cm. The boiling of the mixture is very important; a small quantity of Solvay soda when added appears to produce a beneficial effect. Two special filtrations follow. The clear juice is heated to 105° C. from vapors of the first compartment of the quadruple effect, and is subsequently run into that same compartment. The first compartment of the evaporating apparatus has a heating surface of 90 sq. m.; the three other ones have each 150 sq. m. heating surface. The vapors from the second compartment heat the first, second, and third carbonatating tanks.

The condensed ammoniacal waters are used in the boilers, of which there are seven, having a total heating surface of 900 sq. m. The syrups on leaving the third compartment of the quadruple effect weigh about 15° Bé.; they are forced by a special pump into the sulphurous-acid appliance, where the alkalinity of 0.016 gram of lime per 100 cb. cm. is reached. They are then heated and twice

filtered and returned to the fourth compartment, upon leaving which they test 25° Bé. Heating to 90° C. and mechanical filtration is necessary before sending to the waiting tank in connection with the two vacuum pans. The graining in these continues until 80 hectoliters is obtained, when 70 to 75 hectoliters of inferior syrups from centrifugals, that have undergone the sulphurous-acid treatment, are added. The graining continues until the product contains 6 to 7 per cent of water. The cooling and special mixing lasts six hours, after which the product is run into the centrifugals, the poor and rich swing-outs being kept separate.

After all this complicated treatment the sugar obtained is of a very superior quality and color. The method is more expensive than several other processes, but in some respects there is an economy. The quadruple need not be cleaned until over 10,000 tons of beets have been worked at the factory, and the fact that the pipes, etc., of this apparatus are almost entirely free from deposits is evidence in itself that the juices, etc., must have been well freed from impurities.

Tremblay-lez-Gonesse.—At this beet-sugar factory the baryta process has been introduced with some success. The factory has a Riedel diffusion battery, each diffusor having a capacity of 18 hl.; 160 tons of beets were sliced per diem; from each diffusor 115 liters of juice at 5° density and 40° C. were drawn off for every 100 kilos of beets sliced. The object of baryta was to increase the daily working capacity without any special change in the plant. The amount of lime used was about 1.2 kilos per 100 kilos of beets, while the quantity of baryta was 0.8 kilo per ton of beets. For second carbonatation there was used 0.5 kilo of lime per 100 kilos beets. One and one half kilos caustic lime, to which is added 0.1 kilo caustic baryta, produce the same epurating effects as 2 kilos of lime. The sugar in the former case was dryer and crystallized more rapidly than in the latter. It is said that the volume of residuum scums is 2 per cent less with baryta than with lime alone. After double carbonatation and several filtrations the juices are sent to the triple effect. The syrups leave at 24° Bé., and are then submitted to a sulphuring, etc.

Sainte Marie Kerque factory.—This factory offers some special points of interest, as the after-products are returned to vacuum pan in varied amounts. This plant slices 600 tons of beets per diem. The diffusion battery is in two sections, and there are drawn from the diffusors 110 liters of juice per 100 kilos of beets sliced. There

are 18 diffusors of 38 hl. capacity. The division of the battery is obtained in a very clever manner, with the view of obviating the semicircular revolution of the hopper connecting with the slicer when filling the diffusors. The diffusors 1, 3, 5 . . . 17 communicate with each other and form one battery,[1] while the diffusors 2, 4, 6 . . . 18 form the second battery.

There are five carbonatation tanks, three for the first and two for the second. Each tank is 5.50 m. high (2 m. height of juice), 3.50 long, and 1.20 wide. The volume of juice is 75 hl. The distribution of gas is effected through two semicylindrical pipes. These carbonatators need little or no cleaning, and there is very little deposit. The scum filtration is done with 4 filters, having interior frames of an area of one square meter; there are fifty frames. The scums from second filtration are mixed with the juices of first carbonatation. A very simple combination closes all the exit openings of the filter press in one operation.

The quadruple effect works as follows: First compartment, pressure 0.1 kilo; second compartment, 19 cm. vacuum; third, 43 cm. vacuum; and fourth, 67 cm. vacuum. The fourth compartment has a continuous test-tube attachment, which connects with a force pump and gives at any instant the density of the sample of syrup. The fourth compartment has a sugar arrestor of a new design, and is said to have resulted in considerable economy from a practical standpoint, the sugar arrested amounting to 1500 kilos per diem. The recuperator has 68 divisions over which the steam is obliged to travel on leaving the evaporating apparatus.

The first compartment is connected with a reheater or the so-called circulator, with a heating surface of 20 sq. m. The heating is as follows: The limed diffusion juice is forced through three reheaters, each of 40 sq. m. surface. They are heated with the vapors of the second compartment. The carbonatated juices of the first carbonatators are heated from 60° to 85 C°. in two reheaters of 40 sq. m., which receive their heat from the first compartment. The juice before second carbonatation is brought to 95° C. by two reheaters, heated with steam from the first compartment. The syrups before filtration are raised to 98° C. in a circulator heated with steam from the first compartment.

The two vacuum pans have each a capacity of 200 hl., and connect with the central dry-air pump. The method of graining is

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[1] See Chapter on Diffusion.

very systematic in its working, and has given most satisfactory results. The first strike is made with 72 hl. syrup, which is at a density of 22° to 25° Baumé. After-products and syrup in varying proportions are then introduced. As a first charge 47.5 hl. syrup and 2.5 hl. of after-products from first swing-outs are drawn into the pan. Then the syrup and after-products are introduced in the following proportions: 45 hl. syrup and 5 hl. after-products; 37.5 hl. syrup and 12.5 hl. after-products; 32.5 hl. syrup and 17.5 hl. after-products; 27.5 hl. syrup and 22.5 hl. after-products. The graining continues until the mass contains 5.5 per cent of water. Then follows the sixth introduction of syrup and after-products, 32 hl. of the latter. The mass is run into five RAGOT and TOURNEUR crystallizers of 230 hl. capacity, and after three hours mixing there is added 15 hl. after-products; twelve hours afterward the ninth charge of after-products, 15 hl., and the working in centrifugals follows. In twelve hours the temperature falls from 80° to 40° C. This period could be still further reduced by resorting to special cooling.

The after-products used are previously prepared in a tank of 52 hl. capacity and mixed, the heating being done with steam. The temperature of the product should be that at which the pan is working when the after-product is introduced. Each graining lasts five and one-half hours, and five and sometimes six strikes are made in twenty-four hours. All the after-product obtained is not utilized. There remains 1.5 liters per 100 kilos of beets sliced. This residuum has an actual purity of 69 to 70 and a saline coefficient of 6.2. The farm connected with this factory is 400 hectares (1000 acres). The rotation is first wheat, oats, clover, and then beets for seed. The wheat gives a yield of 45 to 55 hl. per hectare (about 45 to 54 bushels to the acre). The average yield of beets is 45 tons per hectare, or 18 tons to the acre. The fertilizer used for the beets is one ton per hectare (2.5 acres) of powdered defecation scum, distributed in January or February, and 400 to 500 kilos (800 to 1100 lbs.) of sodic nitrate used at time of seeding; when fall plowing with barnyard manure (turned under) is resorted to the defecation scums are not used.

A visit to the Meaux (France) beet-sugar factory.—The MEAUX beet-sugar plant is an excellent example of a well-managed central factory, the location appearing to meet the requirements for the transportation of 300 tons of beets per diem both by rail and water. There are twelve slicing stations, the juices from which are handled

at MEAUX. During an average campaign the factory works an equivalent of 2300 beets per diem. The beets delivered by boats from the river MARNE are carried by an overhead wire rope to the yards of the factory. A small cemented suspended dock holds the boats for the delivery of beets received by the OURCQ Canal. The beets are taken from these and loaded into mono-rail suspended cars, the slant being sufficient to assure their motion, and the roots are then emptied into a large shed. At any desired spot the slanting track forms a loop, and the empty cars are pushed up to a certain elevation, from which they run back to the loading station. For this manœuvre only one man is needed.

The hydraulic carrier is placed at the bottom of the shed at the factory end of the sluice; the beets are raised at the same time as the water and emptied into a MAGUIN washer. The first of these has two stoners, one in front and the other behind. The beets are then thrown by a spiral carrier into a second washer, of very much the same construction as the first. At MEAUX great stress is placed on the thoroughness of the washing. The soil on which most of the beets are cultivated is argillaceous, and, despite all efforts, a certain amount of clay continues to adhere to portions of the surface especially in the case of irregular-shaped beets. The roots upon leaving the washer pass upon a shaker and carrier, to be subsequently raised by a bucket and band lift to the automatic scales, and from these they pass into two hoppers, each of which feeds a vertical beet slicer of the MAGUIN model previously described.

The cossettes obtained are very satisfactory, and the principal advantages of this slicer are the facility and rapidity with which the slicing blades may be changed. The blades or knives of the factory and those of the several slicing stations are all sharpened on special emery wheels. The blades that are exceptionally worn or have broken edges are cut with a specially hard steel tool. Eight automatic PUTSCH sharpeners do the preliminary work, which is finished with the MAGUIN appliances. To facilitate the work the blades are distempered and then tempered in four special furnaces. A very careful system of bookkeeping is conducted in connection with the blades, following their history in great detail from the moment they are adjusted to the slicer until worn out. Beside the sharpening plant are the very complete repair shops, the general arrangement and lighting of which are alone worth a visit to MEAUX; the turning lathes, for example, can handle pieces 2.5 meters in diameter, and modern

machines are arranged so as to meet any emergency that may arise in this model sugar factory.

The cossettes, upon leaving the slicers, fall upon a rake and band-carrier, and are distributed into the diffusors of a battery of the PFEIFFER type; there are 12 diffusors, the capacity of each being 35 hl. The upper closing doors have a considerable diameter and are balanced by counterpoids; their handling offers no difficulty, a hydraulic joint assuring a satisfactory tightness. The battery is emptied by the use of compressed air, a compressor forcing the air into a reservoir of 79 hl. capacity. To eliminate the necessity of stopping or taking off the compressor when the desired pressure is attained, a safety valve acts upon a special register, which is so arranged as to place both sides of the piston in communication, and thus the compressor works without absorption of motive power. To empty the diffusor the hydraulic apparatus closing the bottom is opened and the compressed air is introduced, the emptying lasting about one minute. The entire contents is sent into a double-bottom reservoir, from which a spiral carrier feeds the residuary cossettes into three BERGREEN presses. About 0.25 per cent of sugar is left in this product, which is turned over to the farmers, who feed it to their cattle. The juice from the slicing stations is sent to the central factory through pipes of 100 mm. in diameter; this diameter at the factory end is 200 mm. To prevent, as far as possible, any alteration during its underground transit, 1 per cent of lime is added, which is increased with 0.5 per cent upon reaching its destination. The latter is a milk of lime prepared in a LACOUTURE mixer.

The MEAUX lime kiln has a capacity of 500 cb. m. and is 22 m. high; it is of a French continuous type, in which the limestone is cooked by direct mixing with coke. The stone used comes from Andenne, Belgium; it has a bluish hue, and contains about 99 per cent of lime carbonate. During cooking, approximately 9 per cent of coke is added. The entire volume of juice is combined with 2½ per cent of lime, and carbonatated in four enormous tanks of the LISTRE and VIVIEN model, each having a working capacity of 350 hl.; the final alkalinity is 0.120 per cent of CaO (phenolphthalein test). Two double-acting scum pumps, with automatic plungers of the CAIL type, force the cloudy juice into 15 filter presses. The frames of each of these monster presses have an area of 1 sq. m. The closing of the presses is started by a hand wheel, which brings the frames nearly together; this is followed by a pressure exerted

by two levers, the arms of which may be opened or separated with a right- and left-threaded screw. Before being submitted to the second carbonatation, the juice is run through seven of the double KASALOWSKY filters, then 0.25 per cent of CaO, in the form of milk of lime, is added. The second carbonatation is accomplished in three tanks of 300 hl. working capacity of the same construction as those used for the first carbonatation, the operation continuing until there remains 0.35 per cent of CaO.

An electrical pump forces the juice, under the pressure of 1.5 atmospheres, through five monster filter presses of the same design as previously described. This pump absorbs 115 volts × 150 amperes = 16 kilowatts. The juice is then submitted to a sulphuring in a QUAREZ apparatus, there being four of these placed side by side. A double-acting pump of the BURTON type forces a continuous circulation of the juice in the sulphurer, the operation continuing until an alkalinity of 0.28 per cent CaO is reached. This alkalinity is regulated by the more or less rapid working of the pump, the juice entering and leaving in a continuous stream during this sulphuring. When there is a stoppage in one of the phases of sugar extraction, the pump is stopped and the juice connection with the sulphurer is closed; the juice is then run through seven additional KASALOWSKY filters and into a quadruple effect of the CAIL model. The total heating surface of this apparatus is 2480 sq. m., which means 13,000 tubes unequally distributed through the different compartments, depending upon the volume of circulating vapor of each. One of these compartments has a diameter of 5.5 meters. It is to be noted that their manufacture is exceptionally difficult, owing to the fact that the bronze tube plates are of one piece, and of a size far greater than most turning lathes can accommodate.

The evaporating apparatus has automatic juice-level regulators. The vapors from the last compartment are sent to a central barometric condenser, which is used for all the evaporating and graining apparatus. Two centrifugal pumps supply the injecting water to the condenser at the rate of 750 liters per second, or 65,000 cb. m. per diem. Three moist-air pumps draw the non-condensable gases from the barometric condenser. These pumps have undergone certain changes in their construction in order to be used as dry-air pumps.

The syrups, upon leaving the multiple effect, have a concentration corresponding to 25° or 26° Bé., with an alkalinity of 0.270 per cent; to these are combined the rich after-products from the

centrifugals, which have a purity of 77 to 78. The second-grade sugars are also added; the syrup is then at 27° Bé., and is sulphured until the alkalinity is 0.08 per cent CaO. The test in this case, owing to its neutrality with phenolphthalein, is litmus-paper or liquor; 0.05 per cent Kieselguhr is then added, and this is followed by a heating in two open reheaters with suitable agitators, the syrup then being run through six filter presses. The Kieselguhr is regenerated in boneblack kilns; the organic matter that was absorbed is thus burned, and the carbon formed on the surface of the carapaces of the infusoires, of which they are made up, acts as a decolorizing substance for the juice.

The graining is accomplished in four vacuum pans, two of which have a working capacity of 700 hl., and the two others a working capacity of 450 hl. The pans are vertical and have a coil heating surface. These four pans, also the three apparatuses used for graining the after-products, connect with the barometric condenser. In graining in pan, it is important that the apparatus should have vacuum- and temperature-recording appliances; and, while the exact mistake made by the pan man may not be discovered, one may learn whether or not anything abnormal has occurred during the operation of graining. The massecuite is kept very fluid from start to finish. At the end of the strike, about 40 per cent of the low-grade after-products are introduced into the pan, the operation continuing until the final product contains only about 10 per cent of water.

This massecuite is run into the mixers at 85° C. The apparatus in question is the Ragot-Tourneur device, previously described, the coils, through which circulate water, permitting any desired cooling to be obtained. There are 10 of these mixers, each of which has a capacity of 250 hl. The gradual cooling is effected in eight hours at a temperature of 45° C.; during this operation a small quantity of diluted after-product is added to keep the mass very fluid. After cooling, there is not the slightest evidence of viscosity. A suitable hopper feeds the massecuite lift that empties the product on a spiral carrier placed over the centrifugals. For the swing-out of the "first" there are 40 centrifugals, receiving their motion on top either from a belt or an electric motor. The electric centrifugals, during the period of starting, consume 105 amperes at 115 volts; after an interval of 35 seconds the required speed of 1100 revolutions per minute is attained, the apparatus then absorbing only 16 amperes at 115 volts. The load during each swing-out is 60 to 75

kilos. The after-product is at once separated and a steam-washing follows. As the after-products leave the centrifugals, there is a sort of automatic classification. The syrups run upon a balanced plate; at first there is an abundant flow and the distribution is made in the first gutter. After a short interval the quantity decreases; the after-product is then richer, and the distribution is made in the second gutter. The latter syrups have a purity of 77 to 78, while the former are at 70 to 71. A gang of 12 men can satisfactorily operate the centrifugals, as the sugar-emptying is done on top. M. RAGOT, the manager, has substituted heavy copper ladles for aluminum, the actual muscle-saving for the men being estimated at 16,000 kilogrammeters per diem.

The white sugar thus obtained is very dry, and is raised to the sugar loft by an endless inclined band on which there are linen pockets; the sugar crystals are not broken during the transit. Four sugar mixers remove all possible difference in the shade of color that may exist in the swing-out load from each centrifugal. These sugar mixers have radial divisions and a spiral distributor, and each section is successively filled. At the bottom there is but one hopper, upon which is a conical attachment from which the sugar is emptied into the bags. The sugar loft has a capacity of 2800 bags, and for special fiscal reasons it is filled and emptied daily. When the bags are weighed and closed with special leads, they are slid on to a ropeway which slants in the direction of the canal boat previously mentioned, this transportation demanding an electro-motor of 3 H.P.

The low-grade after-products have an alkalinity of 0.24 per cent CaO. They are submitted to the QUAREZ continuous sulphuring until their alkalinity is reduced to 0.14 per cent as tested with litmus, 0.05 per cent of Kieselguhr then being added to the after-products, which test 31° Bé. They are heated in open reheaters with suitable mixing attachments, and are then run through five PHILIPPE double filters The after-products thus obtained have a satisfactory amber color, and might readily be mistaken for the syrups from the multiple effect. A part of these is returned to the first pan, while another portion is grained in the second pan. The graining nucleus represents 8 per cent of the whole strike, and is obtained with pure syrup in a special, small vacuum pan. Considerable grain is obtained, the mass then being run into one of the after-product pans. These are vertical appliances, each having 450 hl. working capacity and being heated with steam coils. The

graining is done slowly and the mass is kept very fluid. The strike is completed when there remains 10 to 11 per cent of water in the massecuite, which has a purity of 70 to 71. It is emptied from pan at 85° C., and falls into a series of 10 mixers of the same construction as those used for the first, each having a capacity of 250 hl. The product is gradually cooled in 36 hours at the temperature of 35° C. When necessary, a small quantity of diluted after-product is added. The coefficient of supersaturation of the mother liquor is kept low, so as to allow it to crystallize without becoming viscous. Under these conditions it is possible to lower the ultimate after-product that is considered molasses, so that its purity is only 58 to 59. At MEAUX this product is sold for $16 a ton if it polarizes 50.

Three days after the last beets are sliced, all the products of the factory are cleared up. The massecuite of the "seconds" falls directly into the BREGUET electrical centrifugals. The sugar, at 94° to 95° polarization and a 90° to 92° refining yield, is rapidly separated from its adhering syrup, and is at once melted with diluted juice in a funnel. The resulting syrup is at 27° Bé., and is mixed with the concentrated juice in the multiple effect, and, with it, is submitted to a sulphuring. The boilers are arranged in two batteries, one of 22 semi-tubular boilers, each having a heating surface of 160 sq. m., and working under 5 kilos pressure. The other series consists of six boilers, each having 250 sq. m. heating surface and working under a pressure of 8 kilos. They furnish the steam to six LAVAL turbines revolving at a velocity of 12,000 revolutions per minute. All the water needed for the factory is furnished by two centrifugal pumps at the rate of 750 liters per minute, which is received in a cemented reservoir of a capacity sufficient for the factory's running during 20 minutes.

Nordstemmen (Hanover).—While many of the methods used in the NORDSTEMMEN factory, at the time of the writer's visit, have now become obsolete, a description of this well-known plant may still prove interesting. Through the large beet-sheds a narrow channel of water circulates, the center of which is used for the preliminary washing of roots. The juices appeared to be of excellent quality, but a large quantity of boneblack, 16 to 20 per cent of the weight of the beets, was used. The beets were almost perfectly uniform, their average weight being about 400 grams, and the skin hard and compact; notwithstanding the lateness of the season, the beets were in a perfect state of preservation.

At the factory under consideration, HERR BODENBENDER's elu-

tion method was used with considerable success. It consisted in mixing lime with the molasses, and then washing the saccharate with diluted alcohol. The latter dissolves out the salts and organic substances, and there remains, as a final product, a saccharate of lime, used subsequently in the carbonatation and purification of the juices.

The NORDSTEMMEN sugar factory worked about 16,000 kilos of molasses per diem, some of which was purchased. The operation of preparing the saccharate was as follows: 150 liters of water, heated to 60° C., were combined with 108 kilos of pulverized lime, properly screened, and 350 kilos of molasses, marking 75° Brix. The compound was thoroughly mixed for fifteen minutes in a suitable apparatus, the hot mixture being run into rectangular tanks, where it cooled for twenty-four hours. The resulting product was hard, and, after being cut by a suitable machine, the thin slices were used in the elution. There were 16 elutors, having each 150 hectoliters capacity. Alcohol, at 40°, entered the elutor, which had been previously filled with the molassate slices. The alcohol passed, first of all, upon those slices, having been previously washed; then into the second elutor, etc., ending with the one containing the most impure saccharate. The impurities, as previously explained, are soluble in alcohol, and the final saccharate obtained was very pure. The molassate of lime being added to the beet juices, a large quantity of the sugar contained in the molasses was extracted. The alcohol having the impurities in solution was distilled, and again used, the residuum forming an excellent fertilizer, which was in great demand.

The losses during the processes of manufacture were as follows:

0.37, cossettes.
0.12, waste water of diffusion.
0.24, scums of carbonatation.
0.11, boneblack.
0.56, unknown.

Total loss, 1.40 sugar per 100 kilos of beets.

The total sugar extracted from 100 kilos of beets amounted to 11.19 kilos, of which 9.79 kilos were first-grade and 1.40 kilos second-grade sugars.

Trotha (Saxe-Prov.).—In order to compare with the working of the NORDSTEMMEN factory, this plant may be described. MANOURY's

elution method was used there, which, as previously explained, consists in forming a molassate of lime, then washing the latter with diluted alcohol. The molassate, after its impurities were eliminated, was used in a manner similar to other elution methods previously described. It must be said, however, that, instead of producing blocks of the molassate, as at NORDSTEMMEN for example, the molassate of lime was at once produced in porous lumps, which might be rapidly washed.

The preparation of lime by the MANOURY method consisted in immersing the caustic lime for a short time in water, and subsequently pulverizing it. It then fell into a reservoir placed over the mixer, and in communication with the latter was a tank containing the molasses at 45° Bé., one-half per cent of soda having been added. The whole was heated to 87° C., during which time the lime salts of the molasses were changed, some into organic soda salts and carbonate of lime. To about 150 kilos of this molasses were added 600 kilos of pulverized lime, and the resulting molassate of lime was placed on a sieve; the granulated molassate went into the elutors, having false bottoms, and exhaust steam was introduced. Five elutors were connected with one condenser. The circulating alcohol, at 40°, was introduced into the battery, and remained in the elutors about one hour, the salts and organic substances being in that time eliminated. This operation ended, steam was introduced, the remaining alcohol distillated, and the saccharate of lime liquefied, running from the elutor to be subsequently used in defecation. The residuum of the distillation was used for the manufacture of potassa. The yield was 35 kilos of crude sugar at 94° per 100 kilos of molasses. The saccharate obtained contained 95 parts pure lime for 100 parts sugar, and was used in the defecation in the proportion of 37.5 liters of saccharate to 31 hectoliters of juice, or 12.5 per cent of the liquid saccharate of lime. The expense of the method was said to be about one dollar per 100 kilos of molasses worked. This procedure was said to have several advantages, especially in rapidity.

One of the interesting features of the TROTHA factory was, that the purification of the juices was accomplished very quickly, the first defecation lasting but seven minutes, and the second only three minutes. At the TROTHA, as at most German factories, the juice, on leaving the diffusors, ran into two tubular reheaters. The first of these received the vapors of the triple effect before they entered the condenser; the second heated the juices by steam to

a temperature of 45° to 80° R. It is said that a coagulation of the albumen of the juice is effected during the heating, which explains why the carbonatation before mentioned lasts for so short a time. Sulphurous acid is used to decolorize the juices.

The Culmsee beet-sugar factory.—This factory, destroyed by fire two years ago, was visited by the writer some years since; but the information then obtained is not now up to date. However, some recently published data referring to this biggest German factory will prove interesting. The CULMSEE STOCK COMPANY was organized over twenty years ago, and underwent considerable changes for some years, when its slicing capacity was increased to 2500 tons per diem.

DATA FOR THE CULMSEE FACTORY.

Data.	1900–1901.	1899–1900.
Total area (acres) cultivated in beets for the factory.	12,773	11,938
Beets sliced during the campaign (tons)	117,000	159,758
Yield of beets per acre (tons)	9	13.3
Duration of the campaign (days)	59	74
Weight of beets worked per diem (tons)	2,318	2,402

From these figures we conclude that the CULMSEE factory sliced more roots the year previous than during the campaign 1900–1901, while the area devoted to beets was larger in 1900–1901 than during 1899–1900. The average yield per acre was four tons less, the reason for which does not appear. The saccharine quality of the beets and the sugar extraction are shown in the table following:

SUGAR EXTRACTION.

Data.	1900–1901.	1899–1900.
Average saccharine quality of the beet (per cent)...	16.7	14.9
Sugar extracted (tons)	18,776	22,953
Yield first-grade sugar (per cent)	14.5	13.0
Yield second- and third-grade sugars (per cent)	1.5	1 3

The beets polarized very high in 1900–1901, or 1.8 per cent more than in the previous campaign; the difference in weight of sugar extracted was due to the 42,000 supplementary tons sliced. A few figures respecting the residuary molasses are not to be overlooked:

MOLASSES.

Data.	1900-1901.	1899-1900.
Weight of residuary molasses (tons)...............	2735	3290
Yield of molasses (per cent)......................	0.34	2.1
Average selling price of molasses (tons)...........	$11.20	$11.00

These data would indicate that the operation of sugar extraction in 1901 with superior beets was not so well conducted as during 1899-1900.

PRICE OF BEETS, INDEMNITIES, ETC.

Data.	1900-1901.	1899-1901.
Price paid for beets (ton)........................	$5.00	$4.86
Supplementary grant proportional to profits........	0.20	0.13
Indemnity granted for delivery of beets to the factory for distances of more than 4.4 miles per ton.....	0.25	0.25

The plan of allowing farmers additional money for transportation beyond certain limits is most excellent, as the distant tiller is thus encouraged to cultivate beets. Where encouragement is given to cultivate rich beets by dividing the surplus profit with the farmers, they bestow more care on their crop than they would otherwise do.

The cost of working at the CULMSEE factory was greater in 1900-1901 than in 1899-1900, because fuel was excessively high in Germany. Furthermore, the factory hands received increased wages, and another item not to be overlooked is that the campaign lasted only 59 instead of 74 days.

The cost of working per ton of beets sliced in 1900-1901 was $1.94, while in 1899-1900 it was $1.32. The 62 additional cents are partly due to the increase of one dollar a ton for coal. The following table gives the total expenses and profits:

EXPENSES AND PROFITS.

Items.	1901-1901.
Total receipts........................	$955,720
Expenses for beets..................	596,225
Cost of manufacture, including wages. .	214,000
Net profit...........................	145,000

This means 20 per cent profit on the capital invested, showing that, notwithstanding the very low price of sugar on the market, a beet-sugar plant, when worked on a truly scientific basis, becomes an excellent investment for all interested.

The most important Austrian factory visited sliced 2000 tons of beets per diem. The beets as they reach the factory are emptied into the hydraulic carrier combination, consisting of five sections 250 meters long, each of which contains 7000 tons of beets. They are then raised to the two large slicers by automatic carriers, and the resulting cossettes are carried by an endless apron to the diffusors; these together form two batteries, consisting of sixteen compartments of about 70 hl. capacity. The residuum cossettes are pressed until they contain 10 per cent dry matter, and are then conveyed by an electrical carrier to some distance from the factory. There remains 1200 tons of cossettes per diem, all of which finds a ready sale. The raw juices are run through reheaters, and then to mixers, where the milk of lime is added. Special stress is placed upon the temperature. The volume of milk of lime used is very accurately measured. The limed juices then run into the carbonatators, 9 meters high. The residuum scums, weighing 200 tons per diem, are valuable as a fertilizer. The clear juice is run into mechanical filters of the BREITFELD-DANEK type, and after a reheating they are submitted to a second carbonatation, to another filtering and reheating, to the third carbonatation, and are then run through filters to the evaporating apparatus. The scums of second carbonatation are mixed with the first carbonatation juices, which very much simplifies the general arrangement of the plant.

The method is most simple, the resulting juices are very clear and free from calcic salts, and as a consequence the evaporating compartments need very little clearing during the working campaign. No sulphurous acid is used, and the lime added is about 3.5 per cent of the weight of the beets sliced. This lime is made in two KHERN kilns. The evaporating apparatus consists of two huge quadruple effects, one of them having an evaporating surface of 2255 sq. m. and the other 1280 sq. m. The first compartment has a so-called circulator attachment, not unlike a reheater. Between the third and fourth compartments the juice runs through closed filters, whose working can be watched through special observation glasses. The graining is done in four vacuum pans, heated by the vapors from the juices being concentrated. The

swing-out is accomplished in seventeen centrifugals. The green syrups are grained in a FREITAG pan, mixed for seven days in fourteen BOCK crystallizators, and then the mass is run through the second centrifugals. The second sugars are melted in juice and sulphured up to a certain degree of alkalinity, then filtered and added to the first carbonatation juices before the second carbonatation. Under these conditions it is possible to obtain the grade of superior sugar. The consumption of fuel is 140 tons per diem. The consumption of steam is 50 kilos per 100 kilos beets sliced, a result obtained only in a few factories.

APPENDIX.

TABLES.

SPECIFIC-GRAVITY TABLES.

Specific Gravity of Sugar Solutions in Water at +15° C., the Weight of One Volume of Water at that Temperature being Considered = 1.00000.—Scheibler. (N. Z., 25, 40, 1890.)

Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.
0.0	1.00000	5.0	1.01978	10.0	1.04027	15.0	1.06152
1	39	1	1.02018	1	69	1	95
2	78	2	58	2	111	2	238
3	117	3	98	3	53	3	82
4	56	4	139	4	95	4	325
5	94	5	79	5	236	5	68
6	234	6	220	6	78	6	412
7	73	7	60	7	320	7	55
8	312	8	301	8	62	8	99
9	51	9	41	9	404	9	542
1.0	1.00390	6.0	1.02382	11.0	1.04446	16.0	1.06586
1	429	1	422	1	88	1	629
2	68	2	63	2	530	2	73
3	507	3	503	3	72	3	717
4	47	4	43	4	615	4	60
5	86	5	85	5	57	5	804
6	625	6	626	6	99	6	48
7	64	7	66	7	741	7	92
8	704	8	707	8	83	8	936
9	43	9	48	9	826	9	79
2.0	1.00783	7.0	1.02789	12.0	1.04868	17.0	1.07023
1	822	1	829	1	910	1	67
2	61	2	70	2	53	2	111
3	901	3	911	3	95	3	55
4	40	4	52	4	1.05038	4	99
5	80	5	93	5	80	5	243
6	1.01019	6	1.03034	6	123	6	87
7	59	7	75	7	65	7	331
8	99	8	116	8	208	8	75
9	138	9	57	9	50	9	419
3.0	1.01178	8.0	1.03199	13.0	1.05293	18.0	1.07464
1	218	1	240	1	336	1	508
2	57	2	81	2	78	2	52
3	97	3	322	3	421	3	96
4	337	4	63	4	64	4	641
5	77	5	405	5	507	5	85
6	417	6	46	6	49	6	729
7	57	7	87	7	92	7	74
8	96	8	529	8	635	8	818
9	536	9	70	9	78	9	63
4.0	1.01576	9.0	1.03611	14.0	1.05721	19.0	1.07907
1	616	1	53	1	64	1	52
2	56	2	94	2	807	2	96
3	96	3	736	3	50	3	1.08041
4	737	4	77	4	93	4	85
5	77	5	819	5	936	5	130
6	817	6	61	6	79	6	75
7	57	7	902	7	1.06022	7	219
8	97	8	44	8	65	8	64
9	937	9	86	9	109	9	309

Specific Gravity of Sugar Solutions in Water at +15° C.

Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.
20.0	1.08354	25.0	1.10635	30.0	1.12999	35.0	1.15448
1	98	1	82	1	1.13047	1	98
2	443	2	728	2	96	2	548
3	88	3	75	3	144	3	98
4	533	4	821	4	92	4	648
5	78	5	68	5	240	5	98
6	623	6	915	6	89	6	748
7	68	7	61	7	337	7	98
8	713	8	1008	8	85	8	848
9	58	9	55	9	434	9	98
21.0	1.08804	26.0	1.11101	31.0	1.13482	36.0	1.15949
1	49	1	48	1	531	1	99
2	94	2	95	2	79	2	1.16049
3	939	3	242	3	628	3	99
4	84	4	89	4	76	4	150
5	1.09030	5	336	5	725	5	200
6	74	6	83	6	74	6	50
7	120	7	430	7	822	7	301
8	66	8	77	8	71	8	51
9	211	9	524	9	920	9	402
22.0	1.09257	27.0	1.11571	32.0	1.13969	37.0	1.16452
1	302	1	618	1	1.14018	1	503
2	48	2	65	2	66	2	53
3	93	3	712	3	115	3	604
4	439	4	60	4	64	4	55
5	84	5	807	5	213	5	705
6	530	6	54	6	62	6	56
7	76	7	902	7	311	7	807
8	621	8	49	8	60	8	58
9	67	9	96	9	409	9	909
23.0	1.09713	28.0	1.12044	33.0	1.14458	38.0	1.16960
1	59	1	91	1	508	1	1.17010
2	805	2	139	2	57	2	61
3	50	3	86	3	606	3	112
4	96	4	234	4	55	4	63
5	942	5	81	5	705	5	215
6	88	6	329	6	54	6	66
7	1.10034	7	77	7	803	7	317
8	80	8	424	8	53	8	68
9	126	9	72	9	902	9	419
24.0	1.10173	29.0	1.12520	34.0	1.14952	39.0	1.17470
1	219	1	68	1	1.15001	1	522
2	65	2	616	2	51	2	73
3	311	3	63	3	100	3	624
4	57	4	711	4	50	4	76
5	404	5	59	5	200	5	727
6	50	6	807	6	49	6	79
7	96	7	55	7	99	7	830
8	543	8	903	8	349	8	82
9	89	9	51	9	99	9	933

SPECIFIC GRAVITY OF SUGAR SOLUTIONS IN WATER AT +15° C.

Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.
40.0	1.17985	45.0	1.20611	50.0	1.23330	55.0	1.26144
1	1.18036	1	65	1	85	1	201
2	88	2	718	2	441	2	59
3	140	3	72	3	96	3	316
4	92	4	825	4	552	4	73
5	243	5	79	5	607	5	431
6	95	6	933	6	63	6	88
7	347	7	86	7	718	7	546
8	99	8	1.21040	8	74	8	603
9	451	9	94	9	829	9	61
41.0	1.18503	46.0	1.21147	51.0	1.23885	56.0	1.26718
1	55	1	201	1	941	1	76
2	607	2	55	2	97	2	834
3	59	3	309	3	1.24052	3	92
4	711	4	63	4	108	4	949
5	63	5	417	5	64	5	1.27007
6	815	6	71	6	220	6	65
7	68	7	525	7	76	7	123
8	920	8	79	8	332	8	81
9	72	9	633	9	88	9	239
42.0	1.19024	47.0	1.21687	52.0	1.24444	57.0	1.27297
1	77	1	742	1	500	1	355
2	129	2	96	2	56	2	413
3	82	3	850	3	613	3	71
4	234	4	905	4	69	4	529
5	87	5	59	5	725	5	87
6	339	6	1.22013	6	81	6	646
7	92	7	68	7	838	7	704
8	444	8	122	8	94	8	62
9	97	9	77	9	951	9	821
43.0	1.19550	48.0	1.22232	53.0	1.25007	58.0	1.27879
1	602	1	86	1	63	1	938
2	55	2	340	2	120	2	96
3	708	3	95	3	76	3	1.28055
4	61	4	450	4	233	4	113
5	814	5	505	5	90	5	72
6	66	6	59	6	346	6	230
7	919	7	614	7	403	7	89
8	72	8	69	8	60	8	348
9	1.20025	9	724	9	517	9	407
44.0	1.20079	49.0	1.22779	54.0	1.25574	59.0	1.28465
1	132	1	834	1	630	1	524
2	85	2	89	2	87	2	83
3	238	3	944	3	744	3	642
4	91	4	99	4	801	4	701
5	344	5	1.23054	5	58	5	60
6	98	6	109	6	915	6	819
7	451	7	64	7	72	7	78
8	504	8	220	8	1.26030	8	937
9	58	9	75	9	87	9	96

SPECIFIC GRAVITY OF SUGAR SOLUTIONS IN WATER AT +15° C.

Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.
60.0	1.29056	65.0	1.32067	70.0	1.35182	75.0	1.38401
1	115	1	129	1	245	1	67
2	74	2	90	2	308	2	532
3	233	3	251	3	72	3	98
4	93	4	313	4	435	4	663
5	352	5	74	5	99	5	729
6	412	6	436	6	562	6	95
7	71	7	97	7	626	7	860
8	531	8	559	8	90	8	926
9	90	9	620	9	753	9	92
61.0	1.29650	66.0	1.32682	71.0	1.35817	76.0	1.39058
1	710	1	744	1	81	1	124
2	69	2	805	2	945	2	90
3	829	3	67	3	1.36009	3	256
4	39	4	929	4	72	4	322
5	948	5	91	5	136	5	88
6	1.30008	6	1.33053	6	200	6	454
7	68	7	115	7	64	7	520
8	128	8	77	8	328	8	86
9	88	9	239	9	93	9	653
62.0	1.30248	67.0	1.33301	72.0	1.36457	77.0	1.39719
1	308	1	63	1	521	1	85
2	68	2	425	2	85	2	852
3	428	3	87	3	649	3	918
4	89	4	549	4	714	4	85
5	549	5	611	5	78	5	1.40051
6	609	6	74	6	842	6	118
7	69	7	736	7	907	7	84
8	730	8	98	8	71	8	251
9	90	9	861	9	1.37036	9	318
63.0	1.30850	68.0	1.33923	73.0	1.37101	78.0	1.40384
1	911	1	86	1	65	1	451
2	71	2	1.34049	2	230	2	518
3	1.31032	3	111	3	95	3	85
4	93	4	74	4	359	4	652
5	153	5	236	5	424	5	719
6	214	6	99	6	89	6	86
7	74	7	362	7	554	7	853
8	385	8	425	8	619	8	920
9	96	9	88	9	84	9	87
64.0	1.31457	69.0	1.34550	74.0	1.37749	79.0	1.41054
1	518	1	613	1	814	1	121
2	79	2	76	2	79	2	89
3	640	3	739	3	944	3	256
4	701	4	802	4	1.38009	4	323
5	62	5	66	5	74	5	91
6	823	6	929	6	140	6	458
7	84	7	92	7	205	7	526
8	945	8	1.35055	8	70	8	93
9	1.32006	9	118	9	336	9	661

SPECIFIC GRAVITY OF SUGAR SOLUTIONS IN WATER AT +15° C.

Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.	Per cent in weight.	Specific gravity.
80.0	1.41728	85.0	1.45166	90.0	1.48716	95.0	1.52382
1	96	1	236	1	88	1	456
2	864	2	306	2	861	2	531
3	932	3	76	3	933	3	606
4	99	4	446	4	1.49005	4	80
5	1.42067	5	516	5	78	5	755
6	135	6	86	6	150	6	830
7	203	7	656	7	223	7	905
8	71	8	726	8	95	8	79
9	339	9	97	9	368	9	1.53054
81.0	1.42407	86.0	1.45867	91.0	1.49440	96.0	1.53129
1	75	1	937	1	513	1	204
2	543	2	1.46008	2	85	2	79
3	611	3	78	3	658	3	354
4	80	4	149	4	731	4	429
5	748	5	219	5	804	5	504
6	816	6	90	6	77	6	80
7	85	7	360	7	950	7	655
8	953	8	431	8	1.50023	8	730
9	1.43022	9	502	9	96	9	806
82.0	1.43090	87.0	1.46572	92.0	1.50169	97.0	1.53881
1	159	1	643	1	242	1	957
2	227	2	714	2	315	2	1.54032
3	96	3	85	3	88	3	108
4	364	4	856	4	461	4	83
5	433	5	927	5	535	5	259
6	502	6	98	6	608	6	334
7	71	7	1.47069	7	81	7	410
8	640	8	140	8	755	8	86
9	709	9	211	9	828	9	562
83.0	1.43778	88.0	1.47282	93.0	1.50902	98.0	1.54638
1	847	1	354	1	75	1	714
2	916	2	425	2	1.51049	2	90
3	55	3	96	3	123	3	866
4	1.44054	4	568	4	96	4	942
5	123	5	639	5	270	5	1.55018
6	92	6	711	6	344	6	94
7	262	7	82	7	418	7	170
8	331	8	854	8	92	8	247
9	400	9	925	9	566	9	323
84.0	1.44470	89.0	1.47997	94.0	1.51639	99.0	1.55399
1	539	1	1.48069	1	713	1	476
2	608	2	141	2	88	2	552
3	78	3	212	3	862	3	629
4	748	4	84	4	936	4	705
5	817	5	356	5	1.52010	5	82
6	87	6	428	6	84	6	858
7	957	7	500	7	159	7	935
8	1.45026	8	72	8	233	8	1.56012
9	96	9	644	9	308	9	89
						100.0	1.56165

Relation between Degrees Brix and Degrees Baumé.

Degree Baumé.	Degree Brix.	Degree Baumé.	Degree Brix.
5	8.9	40	73.7
10	17.7	41	75.7
15	26.6	42	77.7
20	35.7	43	79.7
25	44.9	44	81.8
30	54.3	45	83.8
35	63.9	46	85.9

Rectification of Indication of the Brix's Saccharimeter on Account of Temperature (Normal Temperature +17.5° C.).—Sachs-Stammer.

Tempera-ture, ° C.	Degrees Brix of the sugar solutions.												
	0	5	10	15	20	25	30	35	40	50	60	70	75
	To subtract from the indication read on the spindle.												
0	0.17	0.30	0.41	0.52	0.62	0.72	0.82	0.92	0.98	1.11	1.22	1.25	1.29
5	0.23	0.30	0.37	0.44	0.52	0.59	0.65	0.72	0.75	0.80	0.88	0.91	0.94
10	0.20	0.26	0.29	0.33	0.36	0.39	0.42	0.45	0.48	0.50	0.54	0.58	0.61
11	0.18	0.23	0.26	0.28	0.31	0.34	0.36	0.39	0.41	0.43	0.47	0.50	0.53
12	0.16	0.20	0.29	0.24	0.26	0.29	0.31	0.33	0.34	0.36	0.40	0.42	0.46
13	0.14	0.18	0.19	0.21	0.22	0.24	0.26	0.27	0.28	0.29	0.33	0.35	0.39
14	0.12	0.15	0.16	0.17	0.18	0.19	0.21	0.22	0.22	0.23	0.26	0.28	0.32
15	0.09	0.11	0.12	0.14	0.14	0.15	0.16	0.17	0.16	0.17	0.19	0.21	0.25
16	0.06	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.12	0.12	0.14	0.16	0.18
17	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.06
	To add to the indication read on the spindle.												
18	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
19	0.06	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.08	0.06
20	0.11	0.14	0.15	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.18	0.15	0.11
21	0.16	0.20	0.22	0.24	0.24	0.25	0.25	0.25	0.26	0.26	0.25	0.22	0.18
22	0.21	0.26	0.29	0.31	0.31	0.32	0.32	0.32	0.33	0.34	0.32	0.29	0.25
23	0.27	0.32	0.35	0.37	0.38	0.39	0.39	0.39	0.40	0.42	0.39	0.36	0.33
24	0.32	0.38	0.41	0.43	0.44	0.46	0.46	0.47	0.47	0.50	0.46	0.43	0.40
25	0.37	0.44	0.47	0.49	0.51	0.53	0.54	0.55	0.55	0.58	0.54	0.51	0.48
26	0.43	0.50	0.54	0.56	0.58	0.60	0.61	0.62	0.62	0.66	0.62	0.58	0.55
27	0.49	0.57	0.61	0.63	0.65	0.68	0.68	0.69	0.70	0.74	0.70	0.65	0.62
28	0.56	0.64	0.68	0.70	0.72	0.76	0.76	0.78	0.78	0.82	0.78	0.72	0.70
29	0.63	0.71	0.75	0.78	0.79	0.84	0.84	0.86	0.86	0.90	0.86	0.80	0.78
30	0.70	0.78	0.82	0.87	.87	.92	0.92	0.94	0.94	0.98	0.94	0.88	0.86
35	1.10	1.17	1.22	1.24	1.30	1.32	1.33	1.35	1.36	1.39	1.34	1.27	1.25
40	1.50	1.61	1.67	1.71	1.73	1.79	1.79	1.80	1.82	1.83	1.78	1.69	1.65
50	—	2.65	2.71	2.74	2.78	2.80	2.80	2.80	2.80	2.79	2.70	2.56	2.51
60	—	3.87	3.88	3.88	3.88	3.88	3.88	3.88	3.90	3.82	3.70	3.43	3.41
70	—	5.17	5.18	5.20	5.14	5.13	5.10	5.08	5.06	4.90	4.72	4.47	4.35
80	—	—	6.62	6.59	6.54	6.46	6.38	6.30	6.26	6.06	5.82	5.50	5.33
90	—	—	8.26	8.16	8.06	7.97	7.83	7.71	7.58	7.30	6.96	6.58	6.37
100	—	—	—	9.87	9.72	9.56	9.39	9.21	9.03	8.64	8.22	7.76	7.42

RELATION BETWEEN THE DIFFERENT GRADUATION OF THERMOMETERS.

° C.	° R.	° F.	° C.	° R.	° F.	° C.	° R.	° F.
−9	− 7.2	+15.8	+45	+36.0	+113.0	+ 99	+ 79.2	+210.2
−8	− 6.4	17.6	46	36.8	114.8	100	80.0	212.0
−7	− 5.6	19.4	47	37.6	116.6	101	80.8	213.8
−6	− 4.8	21.2	48	38.4	118.4	102	81.6	215.6
−5	− 4.0	23.0	49	39.2	120.2	103	82.4	217.4
−4	− 3.2	24.8	50	40.0	122.0	104	83.2	219.2
−3	− 2.4	26.6	51	40.8	123.8	105	84.0	221.0
−2	− 1.6	28.4	52	41.6	125.6	106	84.8	222.8
−1	− 0.8	30.2	53	42.4	127.4	107	85.6	224.6
±0	± 0.0	32.0	54	43.2	129.2	108	86.4	226.4
+1	+ 0.8	33.8	55	44.0	131.0	109	87.2	228.2
2	1.6	35.6	56	44.8	132.8	110	88.0	230.0
3	2.4	37.4	57	45.6	134.6	111	88.8	231.8
4	3.2	39.2	58	46.4	136.4	112	89.6	233.6
5	4.0	41.0	59	47.2	138.2	113	90.4	235.4
6	4.8	42.8	60	48.0	140.0	114	91.2	237.2
7	5.6	44.6	61	48.8	141.8	115	92.0	239.0
8	6.4	46.4	62	49.6	143.6	116	92.8	240.8
9	7.2	48.2	63	50.4	145.4	117	93.6	242.6
10	8.0	50.0	64	51.2	147.2	118	94.4	244.4
11	8.8	51.8	65	52.0	149.0	119	95.2	246.2
12	9.6	53.6	66	52.8	150.8	120	96.0	248.0
13	10.4	55.4	67	53.6	152.6	121	96.8	249.8
14	11.2	57.2	68	54.4	154.4	122	97.6	251.6
15	12.0	59.0	69	55.2	156.2	123	98.4	253.4
16	12.8	60.8	70	56.0	158.0	124	99.2	255.2
17	13.6	62.6	71	56.8	159.8	125	100.0	257.0
18	14.4	64.4	72	57.6	161.6	126	100.8	258.8
19	15.2	66.2	73	58.4	163.4	127	101.6	260.6
20	16.0	68.0	74	59.2	165.2	128	102.4	262.4
21	16.8	69.8	75	60.0	167.0	129	103.2	264.2
22	17.6	71.6	76	60.8	168.8	130	104.0	266.0
23	18.4	73.4	77	61.6	170.6	131	104.8	267.8
24	19.2	75.2	78	62.4	172.4	132	105.6	269.6
25	20.0	77.0	79	63.2	174.2	133	106.4	271.4
26	20.8	78.8	80	64.0	176.0	134	107.2	273.2
27	21.6	80.6	81	64.8	177.8	135	108.0	275.0
28	22.4	82.4	82	65.6	179.6	136	108.8	276.8
29	23.2	84.2	83	66.4	181.4	137	109.6	278.6
30	24.0	86.0	84	67.2	183.2	138	110.4	280.4
31	24.8	87.8	85	68.0	185.0	139	111.2	282.2
32	25.6	89.6	86	68.8	186.8	140	112.0	284.0
33	26.4	91.4	87	69.6	188.6	141	112.8	285.8
34	27.2	93.2	88	70.4	190.4	142	113.6	287.6
35	28.0	95.0	89	71.2	192.2	143	114.4	289.4
36	28.8	96.8	90	72.0	194.0	144	115.2	291.2
37	29.6	98.6	91	72.8	195.8	145	116.0	293.0
38	30.4	100.4	92	73.6	197.6	146	116.8	294.8
39	31.2	102.2	93	74.4	199.4	147	117.6	296.6
40	32.0	104.0	94	75.2	201.2	148	118.4	298.4
41	32.8	105.8	95	76.0	203.0	149	119.2	300.2
42	33.6	107.6	96	76.8	204.8	150	120.0	302.0
43	34.4	109.4	97	77.6	206.6			
44	35.2	111.2	98	78.4	208.4			

Table of the Solubility of Sugar in Water at Different Temperatures, calculated from Herzfeld Tables.*
(Z., 42, 181, 1892.)

(There is dissolved in one part water *n* parts sugar.)

Temperature, C.°	Parts of sugar.	Temperature, C.°	Parts of sugar.	Temperature, C.°	Parts of sugar.	Temperature, C.°	Parts of sugar.
0	1.79						
1	1.80	26	2.12	51	2.62	76	3.44
2	1.81	27	2.14	52	2.65	77	3.48
3	1.82	28	2.16	53	2.67	78	3.52
4	1.83	29	2.17	54	2.70	79	3.57
5	1.84	30	2.19	55	2.73	80	3.62
6	1.86	31	2 21	56	2.75	81	3.66
7	1.87	32	2.23	57	2.78	82	3.71
8	1.88	33	2.25	58	2.81	83	3.76
9	1.89	34	2.27	59	2.84	84	3.81
10	1.90	35	2.29	60	2.87	85	3.86
11	1.91	36	2.30	61	2.90	86	3.92
12	1.92	37	2.32	62	2.93	87	3.98
13	1.94	38	2.34	63	2.96	88	4.03
14	1.96	39	2.36	64	2.99	89	4.09
15	1.97	40	2.38	65	3.03	90	4.15
16	1.98	41	2.40	66	3.06	91	4.21
17	1.99	42	2.42	67	3.09	92	4.28
18	2.01	43	2.44	68	3.13	93	4.35
19	2.02	44	2.46	69	3.16	94	4.42
20	2.04	45	2.48	70	3.20	95	4.48
21	2.05	46	2.51	71	3.24	96	4.55
22	2.07	47	2.53	72	3.28	97	4.63
23	2.08	48	2.55	73	3.31	98	4.71
24	2.09	49	2.58	74	3.35	99	4.79
25	2.11	50	2.60	75	3.40	100	4.87

* The new Herzfeld tables give the percentage only. The foregoing has been separately calculated by Claassen.

Tables for the Boiling-points of Saccharine Solutions,
Based upon the Flourens calculations (Bulletin de la Société ind., 1876, No. 17) and upon the Claassen-Frentzel data.

(a) Boiling-points for Pure Saccharine Solutions.
(general table according to the saccharine percentage.)

Sugar percentage.	Boiling-point at 760 mm. atmospheric pressure.	Increase in the boiling-point.	Sugar percentage.	Boiling-point at 760 mm. atmospheric pressure.	Increase in the boiling-point.
10	100.1	0.1	65	103.9	3.9
20	100.3	0.3	70	105.3	5.3
30	100.6	0.6	75	107.4	7.4
40	101.1	1.1	80	110.3	10.3
50	101.9	1.9	85	114.5	14.5
55	102.4	2.4	90	122.6	22.6
60	103.1	3.1			

(TABLE FOR HIGHER CONCENTRATION ACCORDING TO WATER PERCENTAGE.)

Water percentage.	Increase in temperature of boiling-point. C.°	Water percentage.	Increase in temperature of boiling-point. C.°	Water percentage.	Increase in temperature of boiling-point. C.°	Water percentage.	Increase in temperature of boiling-point. C.°
25	7.35	19	11.5	13.5	16.9	10.50	21.7
24.5	7.85	18.5	11.4	13.25	17.3	10.25	22.15
24	7.9	18	11.8	13	17.7	10	22.6
23.5	8.2	17.5	12.2	12.75	18.05	9.75	23.05
23	8.5	17	12.6	12.50	18.45	9.50	23.55
22.5	8.8	16.5	13.1	12.25	18.85	9.25	24.0
22	9.1	16	13.7	12	19.25	9	24.55
21.5	9.4	15.5	14.3	11.75	19.65	8.75	25.05
21	9.7	15	14.9	11.50	20.05	8.50	25.7
20.5	10.0	14.5	15.5	11.25	20.45	8.25	26.5
20	10.35	14	16.2	11	20.85	8	27.9
19.5	10.7	13.75	16.5	10.75	21.3	7.75	20.0

(*b*) TABLE FOR THE NON-CONCENTRATED AND CONCENTRATED JUICE AND AFTER-PRODUCTS.*
(CLAASSEN, Z., **43**, 267, 1898.)

Degree Brix.	Increase in boiling-point.		Degree Brix.	Increase in boiling-point.	
	Juice. C.°	After-product. C.°		Juice. C.°	After-product. C.°
10	0.2	0.3	55	2.8	3.4
20	0.4	0.6	60	3.5	4.2
30	0.8	1.1	65	4.4	5.3
40	1.4	1.7	70	5.8	6.8
45	1.8	—-	75	—	8.5
50	2.2	2.7			

TABLE OF SPECIFIC HEAT OF SACCHARINE SOLUTIONS.
(CURIN, Oe.-U. Z., **23**, 988, 1894.)*

Degree Brix.	Specific heat.		Degree Brix.	Specific heat.	
	KOPP.	MARIGNAC.		KOPP.	MARIGNAC.
1	0.993	0.994	60	0.605	0.652
10	0.934	0.942	70	0.539	0.594
20	0.868	0.884	80	0.474	0.536
30	0.803	0.826	90	0.408	0.478
40	0.737	0.768	99	0.349	0.426
50	0.671	0.710			

* This table in its original form, as published in the Oe.-U. Z., gives every degree from 1 to 99.

Table of Sugar Losses during Evaporation of Alkaline Juices.
(Herzfeld, Z., 43, 754, 1893.)*

Sugar losses for 100 parts sugar and per hour.

Boiling temperature. C.°	Percentage of sugar in juice.				
	10%	20%	30%	40%	50%
80	0.0444	0.0301	0.0157	0.0179	0.0200
85	0.0615	0.0421	0.0223	0.0262	0.0296
90	0.0790	0.0541	0.0290	0.0344	0.0392
95	0.0965	0.0661	0.0357	0.0427	0.0488
100	0.1140	0.0781	0.0423	0.0508	0.0584
105	0.1385	0.0937	0.0490	0.0588	0.0680
110	0.1630	0.1093	0.0557	0.0667	0.0776
115	0.1749	0.1187	0.0623	0.0748	0.0862
120	0.2823	0.2341	0.1857	0.2269	0.2678
125	0.5330	0.5082	0.4833	0.5939	0.7044
130	2.0553	1.4610	0.8667	1.0235	1.1800
135	3.5776	—	—	—	—
140	5.1000	—	—	—	—

* The original table in the Z. gives the sugar percentages from 10 up to 50 at divisions of 5%; also the temperatures from 110° C. to 120° C.

Claassen's Table showing the Influence of the Purity upon the Yields.
(D. Z. I., 19, 956, 1894.)

(a) Influence of the purity of a massecuite with an unchanging purity of 72 of the after-product.				(b) Influence of the purity of an after-product with an unchanging purity of 91 of a massecuite.		
Massecuite.		Yield of raw sugar polarizing 92° per cent of the massecuite.	Increase in yield for 1 per cent increase in purity.	Purity of the after-product.	Yield of raw sugar polarizing 92° per cent of the massecuite.	Increase in yield for 1 per cent decrease in purity.
Dry substance.	Purity.					
94	88	59.0	—	75	66.7	—
94	89	62.7	3.7	74	67.9	1.2
94	90	66.4	3.7	73	69.1	1.2
94	91	70.1	3.7	72	70.1	1.0
94	92	73.8	3.7	71	71.0	0.9
94	93	77.5	3.7	70	71.9	0.9
94	94	81.2	3.7	69	72.7	0.8
94	95	84.9	3.7	68	73.5	0.8
—	—	—	—	67	74.2	0.7
—	—	—	—	66	74.9	0.7

Solubility of Lime in Water.
(Herzfeld, Z., 47, 820, 1890.)

At the temperature of	Parts of water for one part CaO.	At the temperature of	Parts of water for one part CaO.
15° C.	776	50° C.	1044
20° C.	813	55° C.	1108
25° C.	848	60° C.	1158
30° C.	885	65° C.	1244
35° C.	924	70° C.	1330
40° C.	962	75° C.	1410
45° C.	1004	80° C.	1482

Solubility of Lime in Saccharine Solutions.

According to Lamy there is dissolved in 100 grams of a 10 per cent saccharine solution

At 0° .... 25.0 grams CaO
" 15° .... 21.5 " "
" 30° .... 12.0 " "
" 50° .... 5.3 " "
" 70° .... 2.3 " "
" 100° .... 1.55 " "

The solubility of lime in saccharine solutions does not only depend upon the temperature and the sugar percentage, but also upon the quantity and kind of lime added; also upon the period which the action lasts.

Table of the Amount of Quicklime contained in a Milk of Lime at 15° C.—(Blattner.)

Baumé.	Specific gravity.	CaO in one liter.	CaO per cent in weight.	Baumé.	Specific gravity.	CaO in one liter.	CaO per cent in weight.
	gr.	gr.			gr.	gr.	
1	1.007	7.5	0.745	16	1.125	159	14.13
2	1.014	16.5	1.64	17	1.134	170	15.00
3	1.022	26	2.54	18	1.142	181	15.85
4	1.029	36	3.50	19	1.152	193	16.75
5	1.037	46	4.43	20	1.162	206	17.72
6	1.045	56	5.36	21	1.171	218	18.61
7	1.052	65	6.18	22	1.180	229	19.40
8	1.060	75	7.08	23	1.190	242	20.34
9	1.067	84	7.87	24	1.200	255	21.25
10	1.075	94	8.74	25	1.210	268	22.15
11	1.083	104	9.60	26	1.220	281	23.03
12	1.091	115	10.54	27	1.231	295	23.96
13	1.100	126	11.45	28	1.241	309	24.90
14	1.108	137	12.35	29	1.252	324	25.87
15	1.116	148	13.26	30	1.263	339	26.84

Table of Temperatures corresponding to the Tensions of Saturated Steam.

(Claassen, Z., 43, 268, 1893.)

For 0 to 75 cm. vacuo.

Tension. cm.	Vacuo. cm.	Temperature. C.°	Tension. cm.	Vacuo. cm.	Temperature. C.°	Tension. cm.	Vacuo. cm.	Temperature. C.°	Tension. cm.	Vacuo. cm.	Temperature. C.°
1	75	11.3	17	59	63.0	30.5	45.5	76.3	51	25	89.2
2	74	22.4	17.5	58.5	63.6	31	45	76.7	52	24	89.7
3	73	29.1	18	58	64.2	31.5	44.5	77.1	53	23	90.2
4	72	34.2	18.5	57.5	64.8	32	44	77.5	54	22	90.7
5	71	38.3	19	57	65.4	32.5	43.5	77.9	55	21	91.2
6	70	41.7	19.5	56.5	66.0	33	43	78.2	56	20	91.7
6.5	69.5	43.2	20	56	66.5	33.5	42.5	78.6	57	19	92.2
7	69	44.6	20.5	55.5	67.1	34	42	79.0	58	18	92.6
7.5	68.5	46.0	21	55	67.6	34.5	41.5	79.3	59	17	93.1
8	68	47.2	21.5	54.5	68.1	35	41	79.7	60	16	93.5
8.5	67.5	48.4	22	54	68.7	35.5	40.5	80.0	61	15	94.0
9	67	49.6	22.5	53.5	69.2	36	40	80.4	62	14	94.4
9.5	66.5	50.7	23	53	69.7	37	39	81.0	63	13	94.8
10	66	51.7	23.5	52.5	70.2	38	38	81.7	64	12	95.3
10.5	65.5	52.7	24	52	70.7	39	37	82.4	65	11	95.7
11	65	53.6	24.5	51.5	71.2	40	36	83.0	66	10	96.1
11.5	64.5	54.5	25	51	71.6	41	35	83.6	67	9	96.5
12	64	55.4	25.5	50.5	72.1	42	34	84.2	68	8	96.9
12.5	63.5	56.3	26	50	72.5	43	33	84.8	69	7	97.3
13	63	57.2	26.5	49.5	73.0	44	32	85.4	70	6	97.7
13.5	62.5	58.0	27	49	73.4	45	31	86.0	71	5	98.1
14	62	58.7	27.5	48.5	73.9	46	30	86.5	72	4	98.5
14.5	61.5	59.5	28	48	74.3	47	29	87.1	73	3	98.9
15	61	60.2	28.5	47.5	74.7	48	28	87.7	74	2	99.3
15.5	60.5	61.0	29	47	75.1	49	27	88.2	75	1	99.6
16	60	61.6	29.5	46.5	75.5	50	26	8.87	76	0	100.0
16.5	59.5	62.3	30	46	75.9						

ZEUNER'S TABLE RELATING TO SATURATED STEAM.

Absolute steam tension. Atmosphere of 760 mm. mercury.	Absolute steam tension. Kilograms per sq. cm.	Temperature t in C.	Total heat $\lambda = q + \rho + Apu$. Heat contained in the liquid $= q$.	Vaporisation heat. Latent interior heat ρ.	Vaporisation heat. Latent exterior heat Apu.	Weight of a cubic meter of steam in kilos.
			Calories per kilo.			
0.1	.1033	46.2	46.282	538.848	35.464	0.0687
0.2	.2067	60.5	60.589	527.584	36.764	0.1326
0.3	.3100	69.5	69.687	520.433	37.574	0.1945
0.4	.4133	76.3	76.499	515.086	38.171	0.2553
0.5	.5167	81.7	82.017	510.767	38.637	0.3153
0.6	.6200	86.3	86.662	507.121	39.045	0.3744
0.7	.7234	90.3	90.704	503.957	39.387	0.4330
0.8	.8267	93.9	94.304	501.141	39.688	0.4910
0.9	.9300	97.1	97.543	498.610	39.957	0.5487
1.0	1.0334	100.0	100.500	496.300	40.200	0.6059
1.1	1.1367	102.7	103.216	494.180	43.421	0.6628
1.2	1.2400	105.2	105.710	492.210	40.626	0.7194
1.3	1.3434	107.5	108.104	490.367	40.816	0.7757
1.4	1.4467	109.7	110.316	488.643	40.993	0.8317
1.5	1.5501	111.7	112.408	487.014	41.159	0.8874
1.6	1.6534	113.7	114.389	485.471	41.315	0.9430
1.7	0.7568	115.5	116.269	484.008	41.463	0.9983
1.8	1.8601	117.3	118.059	482.616	41.602	1.0534
1.9	1.9635	119.0	119.779	481.279	41.734	1.0184
2.0	2.0668	120.6	121.417	480.005	41.861	1.1631
2.2	2.2734	123.6	124.513	477.601	42.096	1.2721
2.5	2.5835	127.8	128.753	474.310	42.416	1.4345
2.7	2.7901	130.4	131.354	472.293	42.610	1.5420
3.0	3.1002	133.9	134.989	469.477	42.876	1.7024
3.2	3.3068	136.1	137.247	467.729	43.040	1.8088
3.5	3.6169	139.2	140.438	455.261	43.269	1.9676
3.7	3.8236	141.2	142.453	463.703	43.313	2.0729
4.0	4.1336	144.0	145.310	461.496	43.614	2.2303
4.2	4.3403	145.8	147.114	460.104	43.739	2.3349
4.5	4.6503	148.3	149.708	458.103	43.918	2.4911
4.7	4.8570	150.0	151.360	456.829	43.030	2.5949
5.0	5.1670	152.2	153.741	454.994	44.192	2.7500
5.2	5.3737	153.7	155.262	453.823	44.293	2.8531
5.5	5.6837	155.8	157.471	452.123	44.441	3.0073
5.7	5.8904	157.2	158.880	451.039	44.533	3.1098
6.0	6.2004	159.3	160.938	449.457	44.667	3.2632
6.2	6.4071	160.5	162.255	448.414	44.753	3.3652
6.5	6.7171	162.4	164.181	446.965	44.876	3.5178
6.7	6.9238	163.6	165.428	446.008	44.956	3.6192
7.0	7.2338	165.3	167.243	444.616	45.070	3.7711
7.5	7.7505	168.1	170.142	442.393	45.250	4.0234
8.0	8.2672	170.8	172.888	440.289	45.420	4.2745
8.5	8.7839	173.4	175.514	438.280	45.578	4.5248
9.0	9.3006	175.8	178.017	436.366	45.727	4.7741
9.5	9.8173	178.1	180.408	434.589	45.868	5.0226
10.0	10.3340	180.3	182.719	432.775	46.001	5.2704
10.5	10.8507	182.4	184.927	431.090	46.127	5.5174
11.0	11.3674	184.5	187.065	429.460	46.247	5.7636
11.5	11.8841	186.5	189.131	427.886	46.362	6.0092
12.0	12.4008	188.4	191.126	426.368	46.471	6.2543
12.5	12.9175	190.3	193.060	424.896	46.576	6.4986
13.0	13.4342	192.1	194.944	423.465	46.676	6.7424
13.5	13.9509	193.8	196.766	422.080	46.772	6.9857
14.0	14.4766	195.5	198.537	420.736	46.864	7.2283

For 0 to 1 Atmospheric Pressure.

Tension. cm.	Pressure. cm.	Temperature. C.°	Tension. cm.	Pressure. cm.	Temperature. C.°	Tension. cm.	Pressure. cm.	Temperature. C.°	Tension. cm.	Pressure. cm.	Temperature. C.°
76	0	100.0	96	20	106.6	115	39	111.9	134	58	116.6
77	1	100.4	97	21	106.9	116	40	112.2	135	59	116.8
78	2	100.7	98	22	107.2	117	41	112.4	136	60	117.1
79	3	101.1	99	23	107.5	118	42	112.7	137	61	117.3
80	4	101.4	100	24	107.8	119	43	112.9	138	62	117.5
81	5	101.8	101	25	108.1	120	44	113.2	139	63	117.8
82	6	102.1	102	26	108.4	121	45	113.5	140	64	118.0
83	7	102.5	103	27	108.7	122	46	113.7	141	65	118.3
84	8	102.8	104	28	109.0	123	47	113.9	142	66	118.5
85	9	103.2	105	29	109.3	124	48	114.2	143	67	118.7
86	10	103.5	106	30	109.6	125	49	114.4	144	68	118.9
87	11	103.8	107	31	109.8	126	50	114.7	145	69	119.1
88	12	104.1	108	32	110.1	127	51	114.9	146	70	119.4
89	13	104.4	109	33	110.3	128	52	115.2	147	71	119.6
90	14	104.7	110	34	110.6	129	53	115.4	148	72	119.8
91	15	105.1	111	35	110.9	130	54	115.7	149	73	120.0
92	16	105.4	112	36	111.1	131	55	115.9	150	74	120.2
93	17	105.7	113	37	111.4	132	56	116.1	151	75	120.4
94	18	106.0	114	38	111.7	133	57	116.3	152	76	120.6
95	19	106.3									

Relation between the Varied Methods of Graduating the Vacuo.

Atmospheres of absolute pressure.	Atmospheres of vacuo.	Kilos of absolute pressure.	Kilos of vacuo.	Millimetres of mercury absolute pressure.	Millimetres of mercury vacuo.	Inches of mercury absolute pressure.	Inches of mercury vacuo.
0.1	0.9	0.103	0.930	76	684	3	27
0.2	0.8	0.207	0.826	152	608	6	24
0.3	0.7	0.310	0.723	228	532	9	21
0.4	0.6	0.413	0.620	304	456	12	18
0.5	0.5	0.517	0.516	380	380	15	15
0.6	0.4	0.620	0.413	456	304	18	12
0.7	0.3	0.723	0.310	532	228	21	9
0.8	0.2	0.827	0.206	608	152	24	6
0.9	0.1	0.930	0.103	684	76	27	3
1.0	0.0	1.033	0.000	760	000	30	0

RELATION BETWEEN THE DIFFERENT MODES OF GRADUATING PRESSURE.

Atmospheres of absolute pressure.	Atmospheres of pressure.	Kilos per sq. cm.	Pounds per square inch.
1	0	0	0
2	1	1.0334	14.7
[illegible]	2	2.0668	29.3
4	3	3.1002	44.0
5	4	4.1336	58.7
6	5	5.1670	73.4
7	6	6.2004	88.0
[illegible]	7	7.2338	102.7
9	8	8.2672	117.4
10	9	9.3006	132.1
11	10	10 3340	146.7

TABLE OF LIVE-STEAM CONSUMPTION FOR EVAPORATION, GRAINING, AND REHEATING OF JUICES, ACCORDING TO CLAASSEN.

	Manner of utilising vapors of evaporation.			
	Without utilising the vapors of evaporation, live steam is used for graining and reheating.	Partial use of the vapors of evaporation from first compartment for graining and reheating, and partial use of live steam.	Use of the vapors of evaporation from first compartment, or from the fore-evaporator, for all graining and reheating.	Us[illegible] ora- tion[illegible] the first [illegible]ose of th[illegible] for all h[illegible]
Evaporating appliance.	Consumption of steam for 100 kilos beets.			
	Kilos	Kilos.	Kilos.	Kilos.
Simple effect.	144.4	106 4	96.0	—
Double effect.	91 6	72 3	67.1	—
Triple effect.	74.0	60 9	57 5	—
Quadruple effect.	65 2	55.2	52.6	46.1
Quintuple effect.	60.0	51.8	49.8	44 5
Sextuple effect.	56.4	49.6	47.8	42.5

Remark.—The amount of juice to be evaporated is estimated at 120 kilos per 100 kilos of beets. The heat losses in the machines and pipings are not included in this steam consumption.

VARIOUS DATA.

One cubic meter weighs:

Washed beets	550 to 600	kilos
Fresh residuum, cosettes	600	"
Soured residuum, cosettes	800	"
Furnace coke	420	"
Gas coke	350	"
Limestone	1600	"
Lime	775 to 950	"
Slaked-lime paste	1200	"
Raw sugar, first, loosely piled up	875	"
" " second, loosely piled up	780	"
Hot massecuite	1450 to 1470	"

Specific Weights.

Sugar	1.61
Limestone	2.36 to 2.74
Lime	2.3 to 4.2

Weight of Gases at 0° and 760 mm. Atmospheric Pressure.

1 liter of air	1.293	grams
1 " of oxygen	1.430	"
1 " of nitrogen	1.256	"
1 " of carbonic acid	1.977	"
1 " of sulphurous acid	2.909	"
1 " oxide of carbon	1.250	"
1 " steam at 100° C.	0.506	"
1 " hydrogen	0.089	"
1 " illuminating-gas	0.517	"

Steam, Specific Heat.

At constant pressure	0.4750
" " volume	0.3337

Coefficient of Heat Transmission Data Obtained by Practical Observation and Experiment. (Jelinek.)

Triple effect	1st compartment	37 calories
	2d "	25 "
	3d "	14 "
Quadruple effect	1st compartment	28 calories
	2d "	26 "
	3d "	20 "
	4th "	5 to 6 calories

Vacuum pan for after-products 6 to 7 calories.

" " massecuite, 1st: Until grain formation, 18 calories; During graining, 10 calories; During thickening, 3.7 calories

According to Claassen:

Triple effect	1st compartment, fall of 5°.5 temperature,	juice at 10° Brix, 40 to 50 calories
	2d " " " 7°.5 "	juice at 20° to 25° Brix, 30 to 35 calories
	3d " " " 24° "	juice at 55° to 62° Brix, 15 to 20 calories

Experiments Conducted on a Small Scale at the Atmospheric Pressure (according to Sulzer).

Kind of tube.	Thickness.	Coefficient of heat transmission for the steam used at the temperature of					
	mm.	110 °C.	117 °C.	125 °C.	131.3 °C.	136.5 °C.	141.6 °C.
1. Drawn-copper tube................	2.5	—	47.3	57.2	63.3	62.5	54.2
2. Cast-iron tube, riveted and enameled	2.1	—	33.5	35.3	35.8	37.7	35.3
3. Cast-iron tube, riveted but not enam'd	2.1	—	38.0	36.7	39.2	39.2	37.8
4. Soldered forged-iron boiler tube.....	4.5	—	40.5	42.8	44.8	45.5	43.3
5. Cast-iron tube....................	10	—	25.8	32.2	31.8	31.3	32.3
6. Soldered forged-iron tube..........	13	—	23.2	24.7	26.2	25.5	24.7
7. Steel riveted enameled tube........	1.85	19.0	28.2	31.3	33.0	38.3	—
8. Cast-iron carefully turned tube......	15.25	17.7	28.5	24.5	25.0	26.0	25.7
9. Cast-iron tube special shape........	13.5	26.2	24.8	28.0	28.7	30.0	29.7

In the reheater for diffusion juices with moderate circulation, 2 to 3 calories.
" " " " " " " rapid circulation, 6 to 10 calories.

Utilization of Steam in a Multiple Effect (Claassen).

1 kilo steam evaporates in a simple effect.................	0.9	kilo water
1 " " " " double effect................	1.96	" "
1 " " " " triple effect...................	2.85	" "
1 " " " " quadruple effect..............	3.79	" "
1 " " " " quintuple effect...............	4.72	" "

Decomposition of Sugar in Alkaline Solutions.

1 cb. cm. of a caustic potash 1/10 normal (containing 0.0047 grams K_2O = 0.0028 gram CaO) is neutralized by 0.012 gram of inverted sugar or 0.0114 gram of saccharose.

Analysis of Beets from Different Parts of Germany. (Herzfeld, Z., 48, 828 and 829, 1898.)

Province.	Average weight.		Proportion beets to leaves.	Composition of the beets.				
	Beets.	Leaves.		Sugar.	Total ash.	Soluble ash.	Nitrogen.	Marc.
Silesia...........	416	516	1.24	12.9	0.95	0.83	0.24	4.95
Pomerania.......	340	217	0.64	16.7	0.72	0.45	0.20	4.37
Saxony 1........	458	363	0.71	16.6	1.01	0.82	0.21	5.15
" 2........	320	300	0.94	14.9	0.82	0.60	0.16	5.23
Hanover.........	412	321	0.78	15.2	1.03	0.48	0.17	4.84
Rhineland.......	352	428	1.22	13.7	1.12	0.59	0.18	4.71

The books of the laboratory of a German beet-sugar factory during the campaign 1898–1899 showed the following data:

COMPOSITION OF JUICES AND AFTER-PRODUCTS. (CLAASSEN.)

Data.	Hot aqueous analysis of beets.	Diffusion juices.	1st carbonatation juices.	Filtrated juices.
Brix (degrees)	—	14.4	—	12.2
Polarization	14.66	12.2	—	10.9
Apparent purity quotient	—	84.7	—	89.3
Alkalinity: Phenolphtalein	—	—	0.091	0.049
Rosolic acid	—	—	0.110	0.067
Lime, grams per 100 c.c.	—	—	—	0.043
Invert sugar, per cent	0.17	0.18	—	—
Acidity (per cent c.c. normal acid), phenolphtalein	—	2.1	—	—

Data.	Concentrated juice.		After-products.		Molasses.
	Before sulphuring.	After sulphuring.	From 1st strike.	From 2d strike.	
Brix (degrees)	—	53.3	77.4	76.4	82.8
Polarization	—	48.0	56.9	49.1	47.8
Apparent purity quotient	—	90.1	73.6	64.3	57.7
Alkalinity: Phenolphtalein	0.142	0.049	0.110	0.110	0.080
Rosolic acid	—	0.075	—	—	—
Lime, grams per 100 c.c.	—	0.160	—	—	1.600
Invert sugar, per cent	—	—	—	—	—
Acid (per cent c.c. normal acid), phenolphtalein	—	—	—	—	—

COMPOSITION OF MASSECUITE, SUGAR, AND MOLASSES.

Data.	Concentrated juice (syrup).	Massecuite.			Molasses.	Raw sugar.		
		1st strike (with after-products).	2d strike.	3d strike.		1st grade.	2d grade.	3d grade.
Polarization	47.9	83.5	67.1	58.7	47.8	96.1	92.1	90.8
Water	47.7	7.55	10.42	11.5	21.83	1.50	2.56	2.70
Ash (SO_3)	1.72	3.48	8.52	—	11.78	0.93	2.07	2.81
Non-sugar (organic)	2.67	5.47	13.96	—	18.59	1.47	3.27	3.69
Actual purity	91.6	90.3	74.9	66.4	61.1	—	—	—
Alkalinity, phenolphtalein	0.039	0.064	0.120	0.140	0.080	0.011	0.035	0.030
Lime	0.12	0.27	0.62	0.76	1.60	—	—	—
Ash, percentage of polarization	3.6	4.1	12.7	—	24.6	—	—	—
Organic non-sugar	5.6	6.6	20.8	—	38.9	—	—	—
Lime	0.25	0.32	0.93	1.29	3.3	—	—	—
Alkalinity	0.08	0.08	0.17	0.24	0.16	—	—	—
Inorganic non-sugar: Ash	1.55	1.57	1.64	—	1.58	1.58	1.60	1.32

Analysis of Diffusion Juices and Massecuites from Bohemian Factories During the Campaign 1898–1899.

Andrlik, B. Z., vol. 24, 1899–1900, p. 208–267.*

Factories.	Diffusion Juices.		Massecuites.				
	a	e	a	b	c	d	e
Polarisation	—	—	90.7	90.5	87.6	87.15	85.75
Water	—	—	3.06	4.72	4.55	4.88	6.02
Ash (carbonates)	—	—	2.14	2.16	2.49	2.66	2.32
Non-sugar (organic)	—	—	4.10	3.62	5.36	5.32	5.91
Purity	—	—	93.5	93.9	91.8	91.6	91.2
Non-sugar (inorganic)	—	—	1.9	1.7	2.1	2.0	2.5
Alkalinity (phenolphtalein)	—	—	0.017	0.004	acid	0.028	acid

For 100 Parts Dry Substance.

Factories.	Diffusion Juices.				
	a	[illegible]	c	d	e
Total ash	2.77	3.09	3.81	3.79	3.23
Potash	1.34	1.36	1.72	1.55	1.40
Soda	0.12	0.09	0.16	0.19	0.11
Lime	0.06	0.04	0.03	0.06	0.12
Phosphoric acid	0.37	0.49	0.64	0.49	0.35
Sulphuric acid	0.22	0.17	0.18	0.24	0.24
Chlorine	0.05	0.08	0.07	0.08	0.09
Total nitrogen	0.87	0.90	0.75	1.31	0.80
Albuminoid nitrogen	0.30	0.28	0.25	0.29	0.32
Ammonia nitrogen	0.11	0.15	0.0[illegible]	0.11	0.10
Amido-acid nitrogen	0.43	0.21	0.32	0.38	0.33
Oxalic acid	0.40	0.80	0.91	0.66	0.66

Factories.	Massecuites.				
	a	b	c	d	e
Total ash	2.21	2.24	2.61	2.80	2.47
Potash	1.25	1.19	1.37	1.59	1.41
Soda	0.15	0.20	0.27	0.19	0.13
Lime	0.01	0.02	0.02	0.03	0.04
Phosphoric acid	0.05	0.011	0.003	0.014	0.009
Sulphuric acid	0.13	0.17	0.10	0.14	0.17
Chlorine	0.10	0.06	0.07	0.07	0.07
Total nitrogen	0.37	0.41	0.56	0.45	0.57
Albuminoid nitrogen	0.03	0.03	0.05	0.04	0.04
Ammonia nitrogen	0.06	0.03	0.05	0.03	0.02
Amido-acid nitrogen	0.24	0.26	0.40	0.27	0.44
Oxalic acid	—	—	—	—	—

* The foregoing data have been selected by Claassen here and there from the Andrlik tables.

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